ThermaCAM™ P60

Operator's manual

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Legal disclaimer

All products manufactured by FLIR Systems are warranted against defective materials and workmanship for a period of one (1) year from the delivery date of the original purchase, provided such products have been under normal storage, use and service, and in accordance with FLIR Systems instruction.

All products not manufactured by FLIR Systems included in systems delivered by FLIR Systems to the original purchaser carry the warranty, if any, of the particular supplier only and FLIR Systems has no responsibility whatsoever for such products.

The warranty extends only to the original purchaser and is not transferable. It is not applicable to any product which has been subjected to misuse, neglect, accident or abnormal conditions of operation. Expendable parts are excluded from the warranty.

In the case of a defect in a product covered by this warranty the product must not be further used in order to prevent additional damage. The purchaser shall promptly report any defect to FLIR Systems or this warranty will not apply.

FLIR Systems will, at its option, repair or replace any such defective product free of charge if, upon inspection, it proves to be defective in material or workmanship and provided that it is returned to FLIR Systems within the said one-year period.

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Copyright

Quality assurance

The Quality Management System under which these products are developed and manufactured has been certified in accordance with the ISO 9001 standard.

FLIR Systems is committed to a policy of continuous development; therefore we reserve the right to make changes and improvements on any of the products described in this manual without prior notice.

Patents

This product is protected by patents, design patents, patents pending, or design patents pending.

Swedish Pat. No. 518 836; PCT Pat. Pend. No. PCT/SE00/00739; US Pat. Pend. No. 09/576266; EPC Pat. Pend. No. 00925826.0; China Pat. Pend. No. 00809178.1; Japan Pat. Pend. No. 2000-620406; PCT Pat. Pend. No. PCT/SE01/00983; Swedish Pat. Pend. No. 0101577-5; PCT Pat. Pend. No. PCT/SE02/00857; Swedish Pat. Pend. No. 0200629-4; PCT Pat. Pend. No. PCT/SE03/00307; Swedish Pat. Des. Pend. No. 75530; US Pat. Des. Pend. No. 29/166.626; US Pat. Des. Pend. No. 29/166.627; China Pat. Des. No. ZL02331553.9; China Pat. Des. Pend. No. 02331554.7; UK Pat. Des. No. 3006596; UK Pat. Des. No. 3006597; Japan Pat. Des. Pend. No. 2002-23650; Japan Pat. Des. Pend. No. 2002-23649; Int. Pat. Des. No. DM/061609.

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Table of contents

List of figures

1 Warnings & cautions

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- This equipment generates, uses, and can radiate radio frequency energy and if not installed and used in accordance with the instruction manual, may cause interference to radio communications. It has been tested and found to comply with the limits for a Class A computing device pursuant to Subpart J of Part 15 of FCC Rules, which are designed to provide reasonable protection against such interference when operated in a commercial environment. Operation of this equipment in a residential area is likely to cause interference in which case the user at his own expense will be required to take whatever measures may be required to correct the interference.
- An infrared camera is a precision instrument and uses a very sensitive IR detector. Pointing the camera towards highly intensive energy sources – such as devices emitting laser radiation, or reflections from such devices – may affect the accuracy of the camera readings, or even harm – or irreparably damage – the detector. Note that this sensitivity is also present when the camera is switched off and the lens cap is mounted on the lens.
- Each camera from FLIR Systems is calibrated prior to shipping. It is advisable that the camera is sent in for calibration once a year.
- For protective reasons, the LCD (where applicable) will be switched off if the detector temperature exceeds +60 °C (+149 °F) and the camera will be switched off if the detector temperature exceeds +68 °C (+154.4 °F).
- The camera requires a warm-up time of 5 minutes before accurate measurements (where applicable) can be expected.
- In certain outdoor conditions, the sun can enter the eyepiece and cause damage to the LCD. Use an eyepiece protector when you expect to be using the camera for extended periods of time in outdoor sunlit environments.

2 Welcome!

Thank you for choosing the ThermaCAM™ P60 infrared camera.

The ThermaCAM™ P60 infrared condition monitoring system consists of an infrared camera with a built-in 24° lens, a visual color camera, a laser pointer, an IrDA (infrared communications link), a 4" color LCD on a removable remote control, and a range of accessories. The infrared camera measures and images the emitted infrared radiation from an object. The fact that radiation is a function of object surface temperature makes it possible for the camera to calculate and show this temperature.

The ThermaCAM™ P60 camera is dust- and splash-proof and tested for shock and vibration for use in the most demanding field conditions. It is a handheld, truly portable camera, which is lightweight and operates for more than two hours on one battery pack. A high-resolution color image (infrared & visual) is provided in real-time either in the integral viewfinder or on the remote control LCD.

The camera is very easy to use and is operated by using a few buttons which are conveniently placed on the camera, allowing fingertip control of major functions. A built-in menu system also gives easy access to the advanced, simple-to-use camera software for increased functionality.

To document the object under inspection it is possible to capture and store images on a removable CompactFlash card or in the camera's internal flash memory. It is also possible to store, together with every image, voice comments by using the headset connected to the camera, or text comments, by selecting these from a file with predefined text comments. The images can be analyzed either in the field by using the real-time measurement markers built into the camera software, or in a PC by using FLIR Systems's software for infrared analysis and reporting.

In the PC, the images can not only be viewed and analyzed, but the voice comments can also be played back. FLIR Systems’s software makes it very easy to create complete survey reports (containing numerous infrared images, photos, tables *etc.*) from the inspections.

2.1 About FLIR Systems

With over 30 years experience in IR systems and applications development, and over 30 000 infrared cameras in use worldwide, FLIR is the undisputed global commercial IR industry leader.

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Figure 2.1 FLIR Systems, Boston, USA, FLIR Systems, Danderyd, Sweden, and FLIR Systems, Portland, USA.

As pioneers in the IR industry, FLIR Systems has a long list of 'firsts' in the world of infrared thermography:

- 1965: 1st thermal imaging system for predictive maintenance (Model 650).
- 1973: 1st battery-operated portable IR scanner for industrial applications predictive maintenance (Model 750).
- 1975: 1st TV compatible system (Model 525).
- 1978: 1st dual-wavelength scanning system capable of real-time analog recording of thermal events (Model 780). Instrumental in R & D market development.
- 1983: 1st thermal imaging and measurement system with on-screen temperature measurement.
- 1986: 1st TE (thermo-electrically) cooled system.
- 1989: 1st single-piece infrared camera system for PM (predictive maintenance) and R & D (research & development) with on-board digital storage.
- 1991: 1st Windows-based thermographic analysis and reporting system.
- 1993: 1st Focal Plane Array (FPA) system for PM and R & D applications.
- 1995: 1st full-featured camcorder style FPA infrared system (ThermaCAM).
- 1997: 1st: uncooled microbolometer-based PM/R & D system.
- 2000: 1st thermography system with both thermal and visual imaging.
- 2000: 1st thermography system to incorporate thermal/visual/voice and text data logging.
- 2002: 1st automated thermography system (model P60) to feature detachable remotely controllable LCD, JPEG image storage, enhanced connectivity including USB and IrDA wireless, thermal/visual/voice and text data logging.
- 2002: 1st low-cost ultra-compact hand-held thermography camera (E series). Revolutionary, ergonomic design, lightest IR measurement camera available.

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Figure 2.2 LEFT: FLIR Systems' Thermovision® Model 661. The photo is taken on May 30th, 1969 at the distribution plant near Beckomberga, in Stockholm, Sweden. The camera weighed approx. 25 kg (55 lb), the oscilloscope 20 kg (44 lb), the tripod 15 kg (33 lb). The operator also needed a 220 VAC generator set, and a 10 L (2.6 US gallon) jar with liquid nitrogen. To the left of the oscilloscope the Polaroid attachment (6 kg/13 lb) can be seen. **RIGHT:** FLIR Systems' ThermaCAM Model E2 from 2002 – weight: 0.7 kg (1.54 lb), including battery.

With this tradition of unparalleled technical excellence and innovative achievements, FLIR continues to develop new infrared products, educational venues and applications expertise to meet the diverse demands of thermographers worldwide.

2.1.1 A few images from our facilities

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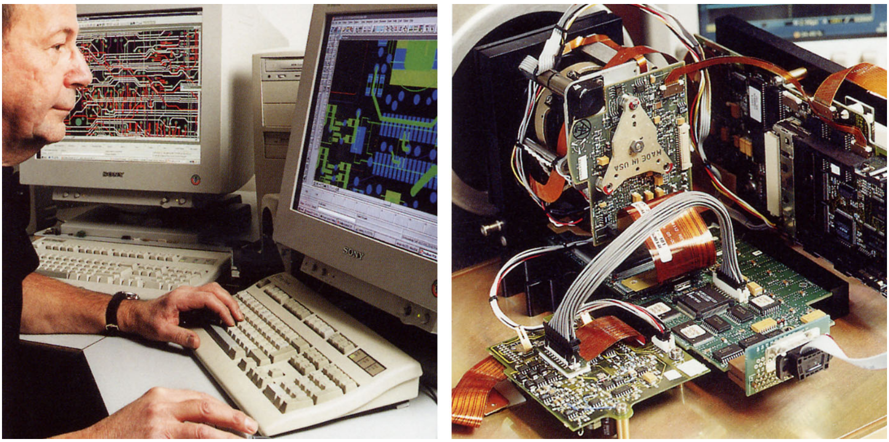

Figure 2.3 LEFT: Development of system electronics; **RIGHT:** Testing of an FPA detector

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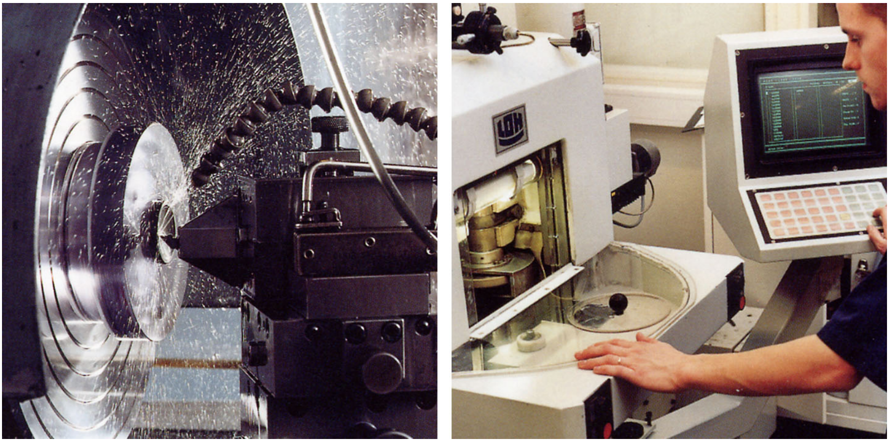

Figure 2.4 LEFT: Diamond turning machine; **RIGHT:** Lens polishing

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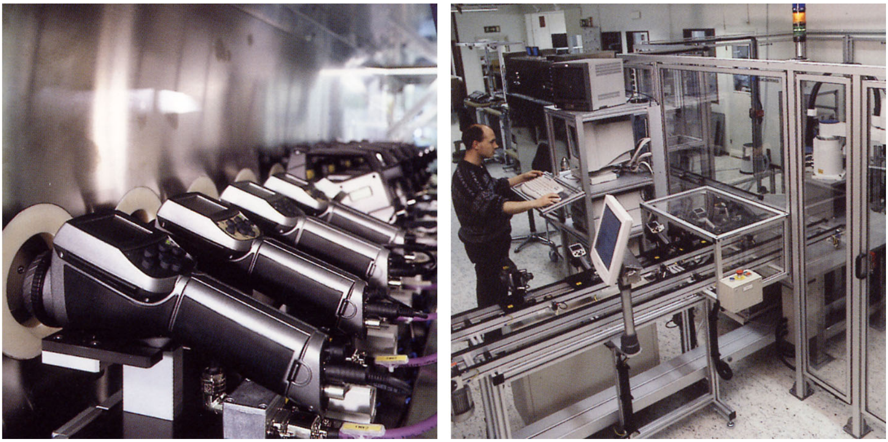

Figure 2.5 LEFT: Testing of IR cameras in the climatic chamber; **RIGHT:** Robot for camera testing and calibration

2.2 Comments & questions

FLIR Systems is committed to a policy of continuous development, and although we have tested and verified the information in this manual to the best of our ability, you may find that features and specifications have changed since the time of printing. Please let us know about any errors you find, as well as your suggestions for future editions, by sending an e-mail to:

documentation@flir.se

NOTE: Do not use this e-mail address for technical support questions. Technical support is handled by FLIR Systems local sales offices.

3 Packing list

The ThermaCAM™ P60 and its accessories are delivered in a hard transport case which typically contains the items below. On receipt of the transport case, inspect all items and check them against the delivery note. Any damaged items must be reported to the local FLIR Systems representative immediately.

No.	Description	Part number	Qty
1	Battery	1 195 268	2
2	Adapter for CompactFlash card	1 909 820	1
3	4" LCD/remote control	1 195 346	1
4	Battery charger	1 195 267	1
5	CompactFlash card	1 909 653	1
6	FireWire cable 4/4 **NOTE:** Depending on your camera configuration, this cable may be an extra option.	1 909 813	1
7	FireWire cable 4/6 **NOTE:** Depending on your camera configuration, this cable may be an extra option.	1 909 812	1
8	Headset	194 109	1
9	Lens cap	1 195 317	1
10	Operator's manual	1 557 945	1
11	Power supply	1 909 528	1
12	Shoulder strap	117 132	1
13	ThermaCAM™ P60	Configuration-dependent	1
14	USB cable	1 195 314	1
15	CVBS video cable	1 909 775	1
16	Video lens 12°	1 909 503	1

NOTE: Please note the following:

- The packing list is, to some degree, subject to customer configuration and may contain more or less items.
- FLIR Systems reserves the right to discontinue models, parts and accessories, and other items, or change specifications at any time without prior notice.

4 System overview

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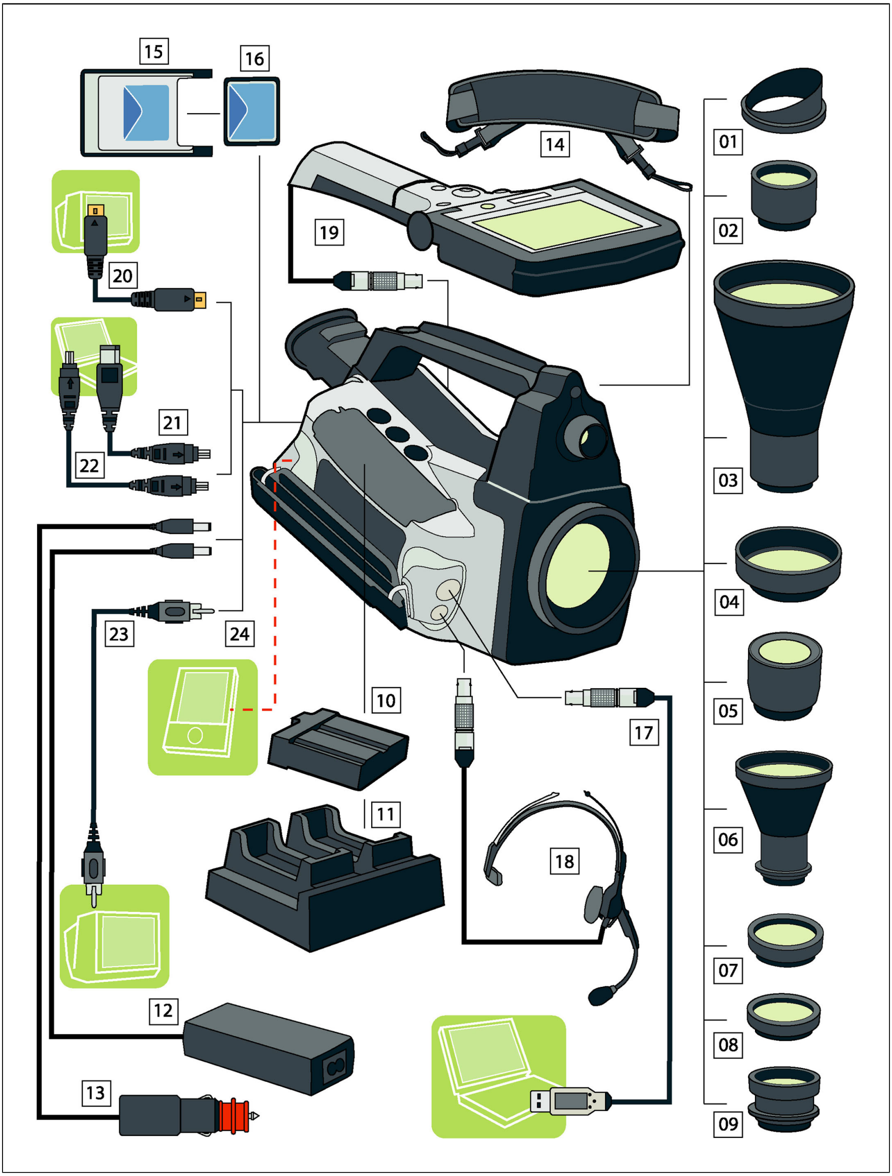

Figure 4.1 System overview

Figure 4.2 Explanations of callouts

Callout	Part No.	Description of part
1	194 560	Protective plastic window
2	1 194 977	Protective window
3	194 579	7° IR lens
4	194 176	12° IR lens
5	194 401	45° IR lens
6	194 702	80° IR lens
7	194 533	64/150 close-up IR lens
8	1 194 978	34/80 close-up IR lens
9	1 700 500	50 µm IR lens
10	1 195 268	Battery
11	1 195 267	2-bay battery charger
12	1 909 528	External power supply
13	1 195 143	Automotive (cigarette lighter) 12 VDC adapter
14	117 132	Shoulder strap
15	1 909 820	Adapter for CompactFlash card
16	1 909 653	CompactFlash card
17	1 195 314	USB cable
18	194 109	Headset
19	1 195 346	Remote control
20	1 909 811	S-Video cable **NOTE:** Depending on your camera configuration, only S-Video or FireWire is supported.
21	1 909 812	FireWire cable 4/6 **NOTE:** Depending on your camera configuration, only S-Video or FireWire is supported.

Callout	Part No.	Description of part
22	1 909 813	FireWire cable 6/6 **NOTE:** Depending on your camera configuration, only S-Video or FireWire is supported.
23	1 909 775	CVBS cable (composite video cable)
24	IrDA	Infrared communication link

5 Connecting system components

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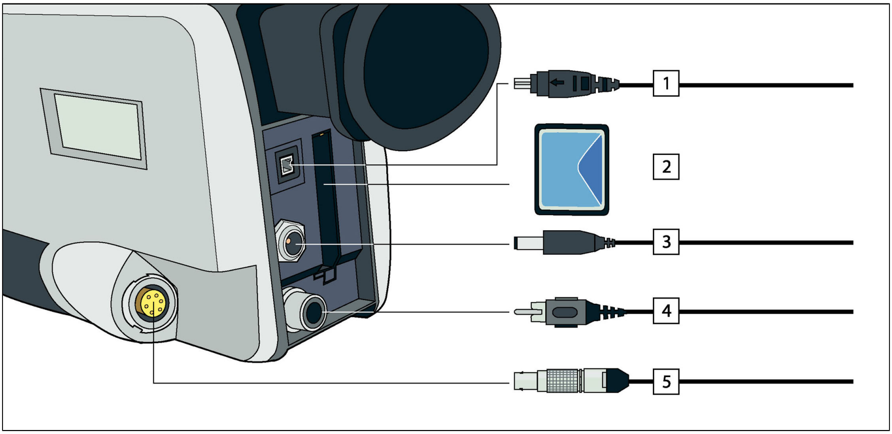

Figure 5.1 How to connect system components, 1: Rear connectors

Figure 5.2 Explanations of callouts

Callout	Explanation
1	FireWire cable Depending on your camera configuration, this may be an S-Video cable instead of a FireWire cable.
2	CompactFlash card
3	Power supply cable
4	CVBS cable (i.e. composite video)
5	Remote control cable

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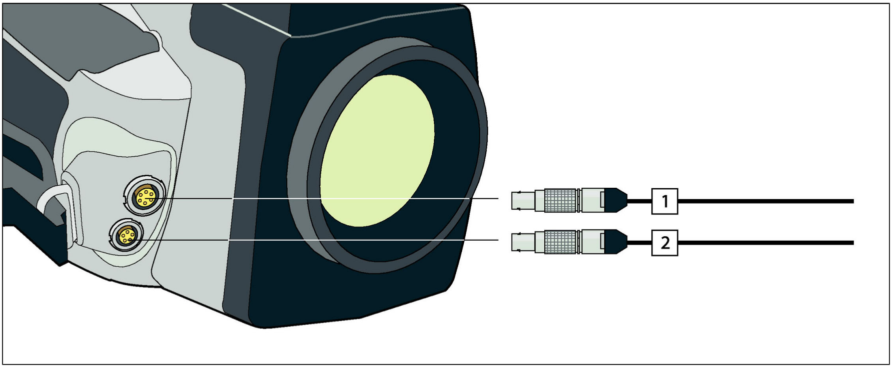

Figure 5.3 How to connect system components, 1: Front connectors

Figure 5.4 Explanations of callouts

Callout	Explanation
1	RS-232 / USB cable. The connector on the camera is also used as a connector for video lamp (see figure 7.3 on page 29).
2	Headset cable

6 Tutorials

6.1 Switching on & switching off the camera

Step	Action
1	Insert a battery into the battery compartment. **SEE ALSO:** For information about inserting a battery, see section 6.7.5 – Inserting & removing the battery on page 23.
2	Briefly press the green ON/OFF button to switch on the camera.
3	Press and hold down the green on/off button for a few seconds to switch off the camera.

SEE ALSO: For information about buttons, see section 7.2 – Keypad buttons & functions on page 33.

6.2 Working with images

6.2.1 Acquiring an image

Step	Action
1	Briefly press the green ON/OFF button to switch on the camera.
2	Point the camera at a warm object, like a face or a hand.
3	Press and hold down the **A** button for one second to adjust the focus.
4	Briefly press the **A** button to autoadjust the camera.

6.2.2 Opening an image

Step	Action
1	Press the joystick to display the horizontal menu bar.
2	Point to **Images** on the **File** menu and press the joystick.
3	Select the image you want to open by moving the joystick up/down or left/right.
4	To recall a selected image, press the joystick.

SEE ALSO: For more information about opening images, see section 8.2.2.1 – Images on page 41.

6.2.3 Freezing & unfreezing an image

Step	Action
1	Press and hold down the **A** button for one second to adjust the focus.
2	Briefly press the **A** button to autoadjust the camera.
3	Briefly press the **S** button to freeze the image. To unfreeze the image, press the **S** button once again.

6.2.4 Saving an image

Step	Action
1	Press and hold down the **A** button for one second to adjust the focus.
2	Briefly press the **A** button to autoadjust the camera.
3	Do one of the following: ▪ Press and hold down the **S** button for a few seconds to save the image ▪ Point to **Save** on the **File** menu and press the joystick

SEE ALSO: For more information about saving images, see section 8.2.2.2 – Save on page 42.

6.3 Working with measurements

6.3.1 Laying out & moving a spot

Step	Action
1	Press the joystick to display the horizontal menu bar.
2	Point to **Add spot** on the **Analysis** menu and press the joystick. A spot will now appear on the screen. The measured temperature will be displayed in the result table in the top right corner of the screen. You are now in *edit mode* and can move the spot in any direction by pressing and moving the joystick. To leave the edit mode, press the **C** button twice. You can also leave the edit mode by holding down the joystick for a few seconds, which will display a shortcut menu.

SEE ALSO: For more information about spots, see section 8.2.3.2 – Add spot on page 50.

6.3.2 Laying out & moving an box

Step	Action
1	Press the joystick to display the horizontal menu bar.

Step	Action
2	Point to **Add box** on the **Analysis** menu and press the joystick. A box will now appear on the screen. The measured temperature will be displayed in the result table in the top right corner of the screen. You are now in *edit mode* and can move the box in any direction by pressing and moving the joystick. To leave the edit mode, press the **C** button twice. You can also leave the edit mode by holding down the joystick for a few seconds, which will display a shortcut menu.

SEE ALSO: For more information about boxes, see section 8.2.3.3 – Add box on page 52.

6.3.3 Laying out & moving a circle

Step	Action
1	Press the joystick to display the horizontal menu bar.
2	Point to **Add circle** on the **Analysis** menu and press the joystick. A circle will now appear on the screen. The measured temperature will be displayed in the result table in the top right corner of the screen. You are now in *edit mode* and can move the circle in any direction by pressing and moving the joystick. To leave the edit mode, press the **C** button twice. You can also leave the edit mode by holding down the joystick for a few seconds, which will display a shortcut menu.

SEE ALSO: For more information about circles, see section 8.2.3.4 – Add circle on page 55.

6.3.4 Laying out & moving a line

Step	Action
1	Press the joystick to display the horizontal menu bar.
2	Point to **Add line** on the **Analysis** menu and press the joystick. A line will now appear on the screen. The measured temperature will be displayed in the result table in the top right corner of the screen. You are now in *edit mode* and can move the line in any direction by pressing and moving the joystick. To leave the edit mode, press the **C** button twice. You can also leave the edit mode by holding down the joystick for a few seconds, which will display a shortcut menu.

SEE ALSO: For more information about lines, see section 8.2.3.5 – Add line on page 58.

6.3.5 Creating & changing an isotherm

Step	Action
1	Press the joystick to display the horizontal menu bar.
2	Point to **Add isotherm** on the **Analysis** menu and press the joystick. An isotherm will now be added to your image. The isotherm levels will be displayed in the result table in the top right corner of the screen. You are now in *edit mode* and can change the isotherm levels by moving the joystick up/down. To leave the edit mode, press the **C** button twice. You can also leave the edit mode by holding down the joystick for a few seconds, which will display a shortcut menu.

SEE ALSO: For more information about creating & changing an isotherm, see section 8.2.3.6 – Add isotherm on page 61.

6.3.6 Resizing a measurement marker

NOTE: This example procedure, which applies to all types of measurement markers, assumes that you have laid out only one measurement box on the screen and exited the menu system.

Step	Action
1	Press the joystick to display the horizontal menu bar.
2	Point to **Edit mode** on the **Analysis** menu and press the joystick. This will display eight gray handles on the box.
3	Press the joystick once again. This will make the gray handles turn yellow.
4	Move the joystick left/right or up/down to select one of the yellow handles.
5	To resize the box, press the joystick and move it in any direction, then press the joystick again to confirm the size.
6	Press the **C** button once to leave the edit mode.

6.4 Working with alarms

You can choose between the following alarm outputs:

- a silent alarm, which, will make the background of the corresponding measurement function turn red when an alarm is triggered
- an audible alarm, which, compared to the silent alarm, also triggers a 'beep'

A settings can also be made in the camera so that an alarm output takes into account the reference temperature. A typical application when you would want to

use an alarm that takes into account the reference temperature is screening of people for face temperature detection.

Firstly, the reference temperature is set by screening 10 persons with normal face temperature. The camera puts each of these 10 results in an internal camera buffer and calculates the average temperature value after having discarded the two highest and two lowest values in the event of erroneous samples. Every time a new sample is saved to the internal buffer, the oldest sample will be discarded and a new reference temperature will be calculated 'on the fly'.

Using an alarm that takes into account the reference temperature means that an alarm output will only be triggered if the temperature value exceeds the sum of the average temperature value in the buffer + the user-defined delta alarm offset value.

6.4.1 Setting the reference temperature

Step	Action
1	Press the joystick to display the vertical menu bar.
2	Point to **Buttons** on the **Setup** menu and press the joystick.
3	In the **Buttons setup** dialog box, press the joystick up/down to go to **F1** or **F2**.
4	Press the joystick left/right to select **Update ref temp**.
5	Press the joystick to confirm the choice and leave the dialog box.
6	Now point to **Image** on the **Setup** menu and press the joystick.
7	Press the joystick up/down to go to **Shutter period**. Although the shutter period works independently of other functions described in this document, FLIR Systems recommends that **Short** is selected when using the camera for detection of face temperature. **NOTE:** Selecting **Normal** will calibrate the camera at least every 15th minute, while selecting **Short** will calibrate the camera at least every 3rd minute.
8	Pointing the camera to the first person with a normal face temperature and pressing the **F1** or **F2** button will display the message **Sampled nn.n °C**.
9	After having carried out the same procedure on the following 9 persons, you can do one of the following: ▪ Actively continue to sample every new person by the F1 or F2 button, and let the camera update the reference temperature ▪ Stop sampling and let the camera trigger an alarm as soon as the alarm conditions are met (> reference temperature + delta alarm value)

6.4.2 Setting up a silent alarm

Step	Action
1	Press the joystick to display the vertical menu bar.
2	Point to **Alarm** on the **Setup** menu and press the joystick to display the **Alarm setup** dialog box.
3	Select **Type** by pressing the joystick left/right. This setting defines whether the alarm should be triggered when the temperature exceeds or drops below the alarm temperature.
4	Select **Function** by pressing the joystick left/right. This setting defines what measurement function should be used to trigger the alarm.
5	Select **Identity** by pressing the joystick left/right to assign an identity to the function selected above.
6	Select **Output** by pressing the joystick left/right until **Silent** is highlighted.
7	Specify the **Alarm temp** by pressing the joystick left/right. **NOTE: Alarm temp** will only be available if **Set from ref temp** has been disabled below.
8	Specify whether the alarm temperature should be set from the reference temperature or not by pressing the joystick left/right.
9	Specify **Delta alarm** by pressing the joystick left/right. **NOTE: Delta alarm** will only be available if **Set from ref temp** has been enabled above.

6.4.3 Setting up an audible alarm

Step	Action
1	Press the joystick to display the vertical menu bar.
2	Point to **Alarm** on the **Setup** menu and press the joystick to display the **Alarm setup** dialog box.
3	Select **Type** by pressing the joystick left/right. This setting defines whether the alarm should be triggered when the temperature exceeds or drops below the alarm temperature.
4	Select **Function** by pressing the joystick left/right. This setting defines what measurement function should be used to trigger the alarm.
5	Select **Identity** by pressing the joystick left/right to assign an identity to the function selected above.

Step	Action
6	Select **Output** by pressing the joystick left/right until **Beep** is highlighted.
7	Specify the **Alarm temp** by pressing the joystick left/right. **NOTE: Alarm temp** will only be available if **Set from ref temp** has been disabled below.
8	Specify whether the alarm temperature should be set from the reference temperature or not by pressing the joystick left/right.
9	Specify **Delta alarm** by pressing the joystick left/right. **NOTE: Delta alarm** will only be available if **Set from ref temp** has been enabled above.

6.5 Changing level & span

6.5.1 Changing the level

Step	Action
1	Press the joystick to display the horizontal menu bar.
2	If the camera is in continuous adjust mode, point to **Manual adjust** on the **Image** menu and press the joystick.
3	Change the level by moving the joystick up/down. An arrow pointing upwards or downwards will be displayed.
4	Press the joystick to leave level/span mode.

NOTE: You can also change the level by pointing to **Level/Span** on the **Image** menu, and then change the level by moving the joystick up/down.
SEE ALSO: For more information about level, see section 8.2.4.4 – Level/Span on page 65.

6.5.2 Changing the span

Step	Action
1	Press the joystick to display the horizontal menu bar.
2	If the camera is in continuous adjust mode, point to **Manual adjust** on the **Image** menu and press the joystick.
3	Change the span by moving the joystick left/right. Two arrows pointing away from each other or towards each other will be displayed.
4	Press the joystick to leave level/span mode.

NOTE: You can also change the span by pointing to **Level/Span** on the **Image** menu, and then change the span by moving the joystick left/right.
SEE ALSO: For more information about span, see section 8.2.4.4 – Level/Span on page 65.

6.6 *Changing system settings*

6.6.1 Changing the language

Step	Action
1	Press the joystick to display the horizontal menu bar.
2	Point to **Local settings** on the **Setup** menu and press the joystick.
3	Move the joystick up/down to select **Language**.
4	Move the joystick left/right to change the language.
5	Press the joystick to confirm your changes and leave the dialog box. **NOTE:** Changing the language will make the camera restart the camera program. This will take a few seconds.

6.6.2 Changing the temperature unit

Step	Action
1	Press the joystick to display the horizontal menu bar.
2	Point to **Local Settings** on the **Setup** menu and press the joystick.
3	Move the joystick up/down to select **Temp unit**.
4	Move the joystick left/right to change the temperature unit.
5	Press the joystick to confirm your changes and leave the dialog box.

6.6.3 Changing the date format

Step	Action
1	Press the joystick to display the horizontal menu bar.
2	Point to **Local Settings** on the **Setup** menu and press the joystick.
3	Move the joystick up/down to select **Date format**.
4	Move the joystick left/right to change the date format.
5	Press the joystick to confirm your changes and leave the dialog box.

6.6.4 Changing the time format

Step	Action
1	Press the joystick to display the horizontal menu bar.
2	Point to **Local Settings** on the **Setup** menu and press the joystick.
3	Move the joystick up/down to select **Time format**.
4	Move the joystick left/right to change the time format.
5	Press the joystick to confirm your changes and leave the dialog box.

6.6.5 Changing date & time

Step	Action
1	Press the joystick to display the horizontal menu bar.
2	Point to **Date/time** on the **Setup** menu and press the joystick.
3	Move the joystick up/down to select year, month, day, minute and second.
4	Move the joystick left/right to change each parameter.
5	Press the joystick to confirm your changes and leave the dialog box.

6.7 Working with the camera

6.7.1 Mounting an additional lens

NOTE: Before trying to remove fingerprints or other marks on the lens elements, see section 11.2 – Lenses on page 86.

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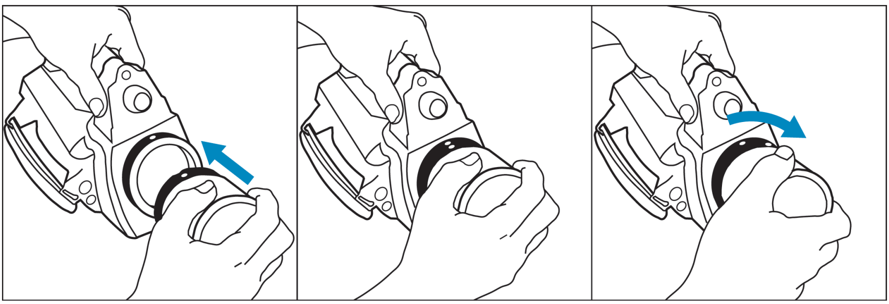


Figure 6.1 Mounting an additional lens

Step	Action
1	Make sure the index mark on the IR lens is lined up with the index mark on the camera.
2	Carefully push the lens into the lens recess. **NOTE:** Do not use excessive force.
3	Rotate the lens 30° clock-wise.

6.7.2 Focusing the camera using autofocus

Step	Action
1	Press the green ON/OFF button to switch on the camera.
2	Press and hold down the **A** button for one second to adjust the focus. An indicator will be displayed on the left side of the screen when focusing.

6.7.3 Focusing the camera manually

Step	Action
1	Press the green ON/OFF button to switch on the camera.
2	Adjust the focus by moving the joystick up/down. An indicator will be displayed on the left side of the screen when focusing.

6.7.4 Using the electronic zoom

Step	Action
1	Press the green ON/OFF button to switch on the camera.
2	Adjust the zoom factor by moving the joystick left/right. An indicator will be displayed on the left side of the screen when zooming.

6.7.5 Inserting & removing the battery

NOTE: The camera is shipped with charged batteries. To increase battery life, the battery should be fully discharged and charged a couple of times. You can do this by using the camera until the battery is fully depleted.

6.7.5.1 Inserting the battery

10397003;2

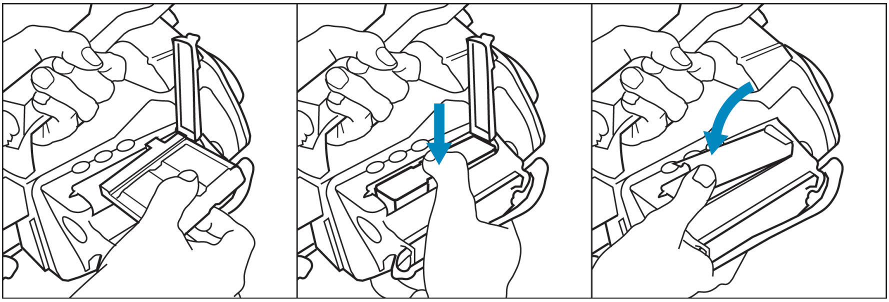


Figure 6.2 Inserting the battery

Step	Action
1	Open the lid of the battery compartment by pressing its locking mechanism.
2	Push the battery into the battery compartment until the battery release spring locks.
3	Close the lid of the battery compartment.

6.7.5.2 Removing the battery

10397103;2

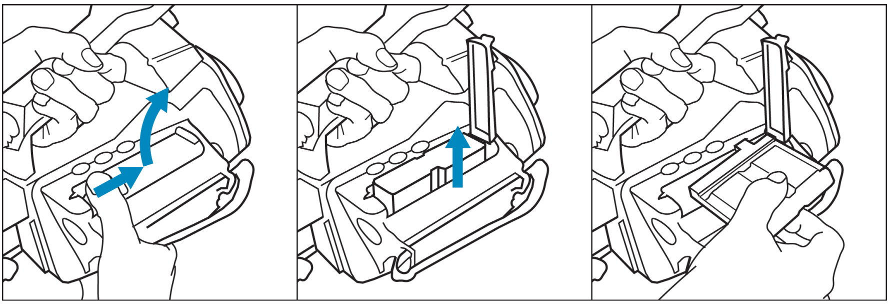


Figure 6.3 Removing the battery

Step	Action
1	Open the lid of the battery compartment by pressing its locking mechanism.
2	The battery release spring will push out the battery from the battery compartment.
3	Close the lid of the battery compartment.

SEE ALSO: For more information about the battery system, see section 9 – Electrical power system on page 80.

6.7.6 Removing & attaching the remote control from the camera handle

NOTE: The remote control is mounted on the camera handle by means of a fixed front latch and a rear spring-loaded latch. See the figure on page 31.

6.7.6.1 Removing the remote control

10397203;3

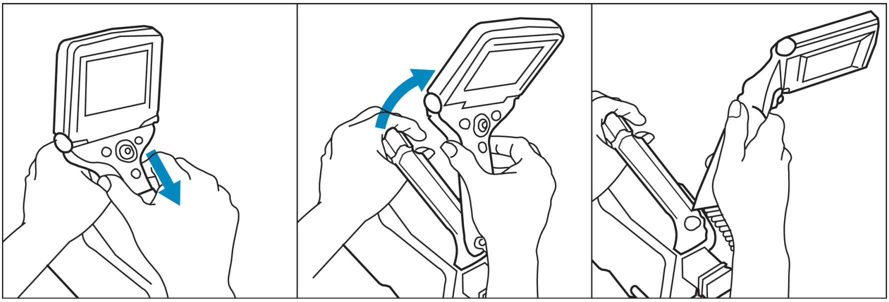


Figure 6.4 Removing the remote control

Step	Action
1	Firmly hold the camera in your left hand and grab the handle of the remote control in your right hand.
2	Pull the handle backwards until the front of the handle is released from its latch.
3	You can now remove the remote control from the camera handle.

6.7.6.2 Attaching the remote control

10397303;3

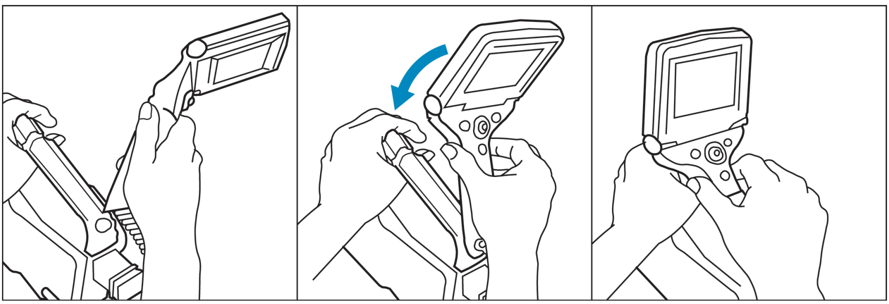


Figure 6.5 Attaching the remote control

Step	Action
1	Firmly hold the camera in your left hand and hold the remote control in your right hand.
2	Align the remote control handle with the camera handle so that the rear end of the remote control handle mates with the rear spring-loaded latch.
3	Pull the remote control handle backwards and then push it down – towards the camera handle – to lock it between the two latches.

7 Camera overview

7.1 Camera parts

10394103;4

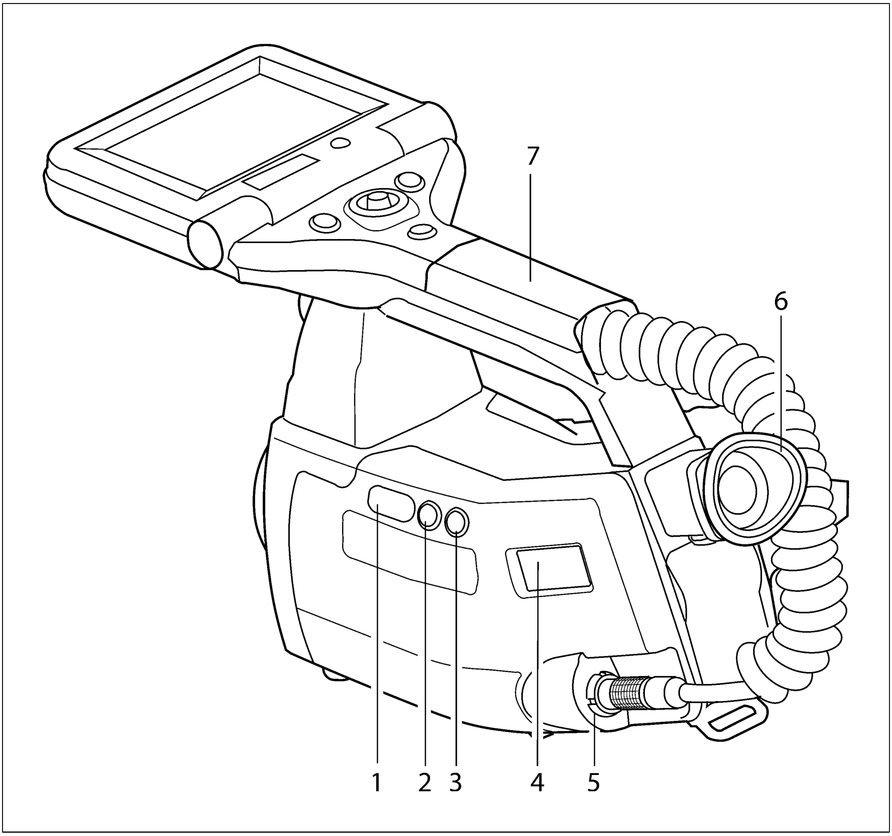


Figure 7.1 Camera parts, 1

Callout	Description of part
1	+/– buttons **SEE ALSO:** For more information about the functionality of this button, see section 7.2 – Keypad buttons & functions on page 33.

Callout	Description of part
2	**F1** button **SEE ALSO:** For more information about the functionality of this button, see section 7.2 – Keypad buttons & functions on page 33.
3	**F2** button **SEE ALSO:** For more information about the functionality of this button, see section 7.2 – Keypad buttons & functions on page 33.
4	Camera status LCD **SEE ALSO:** For more information about the LCD, see section 7.5 – Camera status LCD on page 35.
5	Connector for remote control
6	Viewfinder
7	Removable remote control with 4" LCD

10394303;4

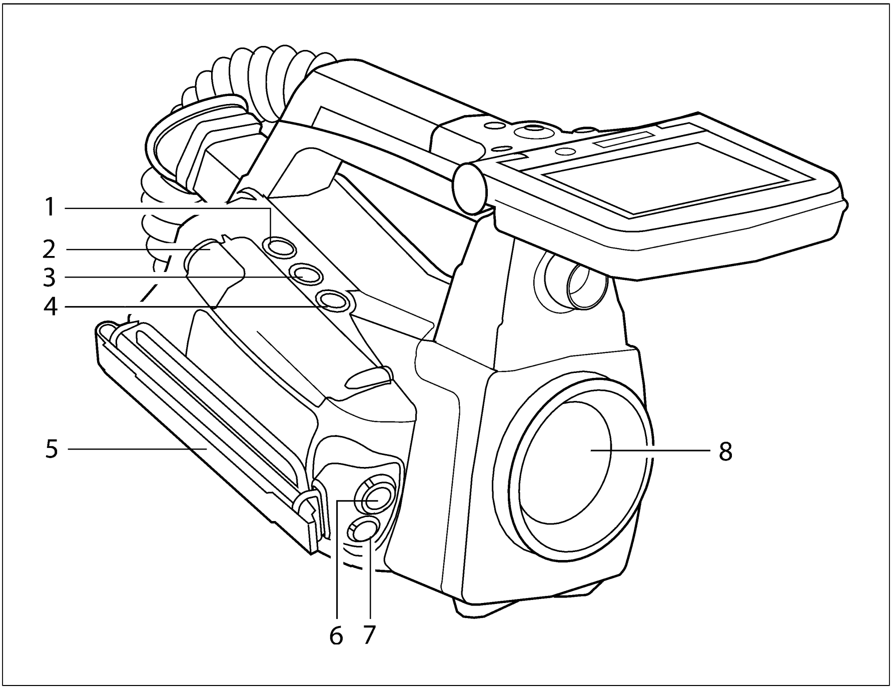


Figure 7.2 Camera parts, 2

Callout	Description of part
1	**C** button **SEE ALSO:** For more information about the **C** button, see section 7.2 – Keypad buttons & functions on page 33.
2	Lid of the battery compartment
3	**S** button **SEE ALSO:** For more information about the **S** button, see section 7.2 – Keypad buttons & functions on page 33.
4	**A** button **SEE ALSO:** For more information about the **A** button, see section 7.2 – Keypad buttons & functions on page 33.
5	Hand strap
6	RS-232/USB connector The connector is also used as a connector for video lamp (see figure 7.3 on page 29).
7	Headset connector
8	Lens

10563403;1

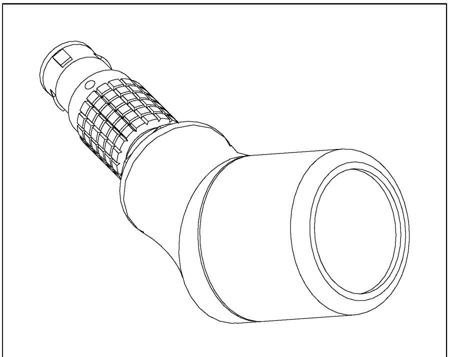


Figure 7.3 Video lamp, to be inserted in the RS-232/USB connector. The video lamp will automatically be switched on when the user switches to visual mode.

10394403;4

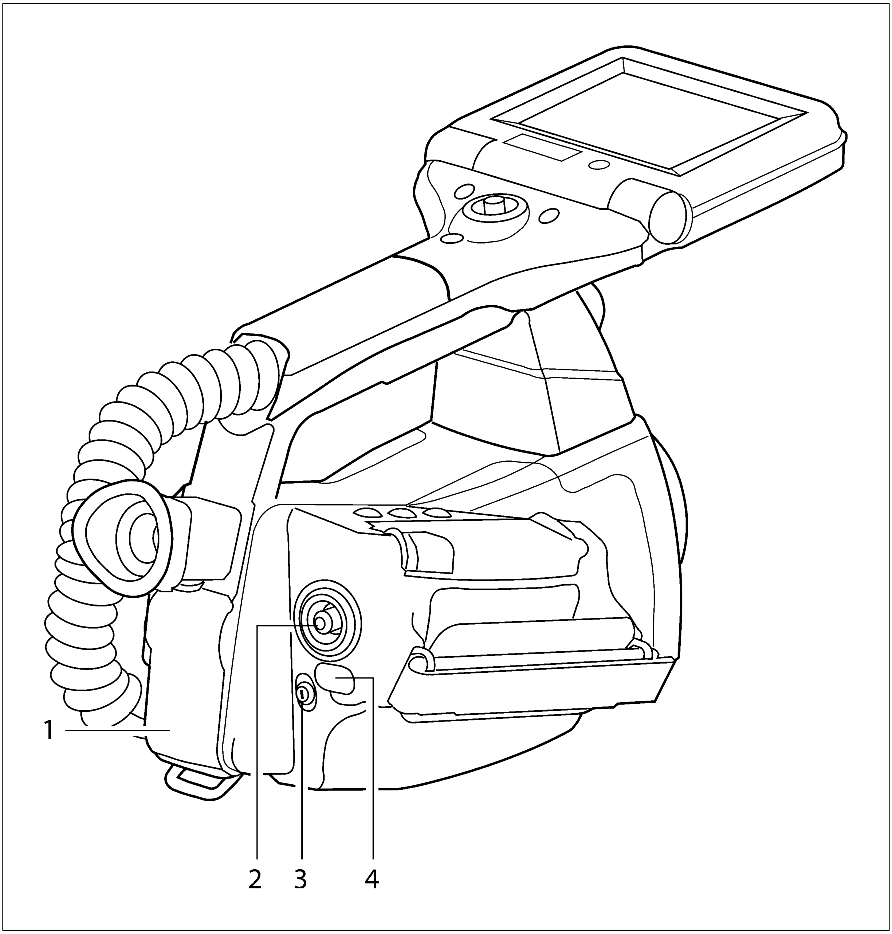


Figure 7.4 Camera parts, 3

Callout	Description of part
1	Cover for additional connectors
2	Joystick **SEE ALSO:** For more information about the joystick, see section 7.2 – Keypad buttons & functions on page 33.
3	**ON/OFF** button (green) **SEE ALSO:** For more information about the ON/OFF button, see section 7.2 – Keypad buttons & functions on page 33.

Callout	Description of part
4	IrDA infrared communication link (to communicate with the camera using a PDA, laptop computer *etc.*) **SEE ALSO:** For more information about using IrDA, see section 7.4 – IrDA infrared communication link on page 35.

10394603;4

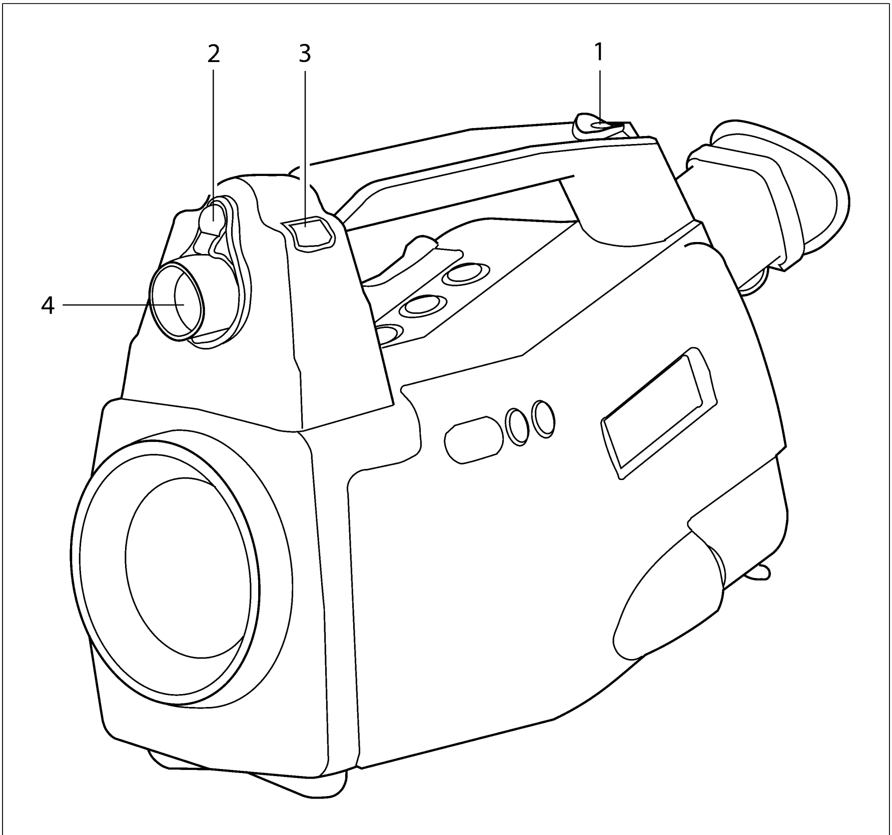


Figure 7.5 Camera parts, 4

Callout	Description of part
1	Spring-loaded locking latch for the remote control

Callout	Description of part
2	Laser LocatIR with lens cap **NOTE:** Please note the following: ■ A laser icon appears on the screen when the Laser LocatIR is switched on. ■ Since the distance between the laser beam and the image center will vary by the target distance, Laser LocatIR should only be used as an aiming aid. Always check the LCD to make sure the camera captures the desired target. ■ Do not look directly into the laser beam. ■ When not in use, the Laser LocatIR should always be protected by the lens cap. **SEE ALSO:** For more information about Laser LocatIR, see section 7.6 – Laser LocatIR on page 37.
3	Button for Laser LocatIR **SEE ALSO:** For more information about Laser LocatIR, see section 7.6 – Laser LocatIR on page 37.
4	Visual camera **SEE ALSO:** For more information about the visual camera, see section 7.7 – Visual camera on page 37.

10395003;3

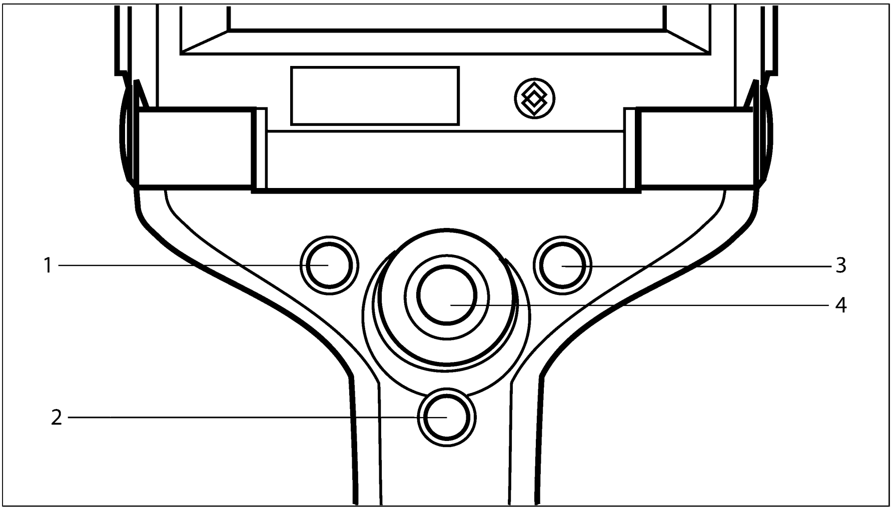


Figure 7.6 Removable remote control

Callout	Description of part
1	**S** button **SEE ALSO:** For more information about the **S** button, see section 7.2 – Keypad buttons & functions on page 33.
2	**C** button **SEE ALSO:** For more information about the **C** button, see section 7.2 – Keypad buttons & functions on page 33.
3	**A** button **SEE ALSO:** For more information about the **A** button, see section 7.2 – Keypad buttons & functions on page 33.
4	Joystick **SEE ALSO:** For more information about the joystick, see section 7.2 – Keypad buttons & functions on page 33.

7.2 Keypad buttons & functions

Figure 7.7 Camera buttons – explanations

Button	Comments
ON/OFF	▪ Press briefly to switch on the camera ▪ Press and hold down for a few seconds to switch off the camera
A	▪ Press briefly to autoadjust the camera ▪ Press and hold down for a few seconds autofocus the camera
S	▪ Press briefly to freeze an image ▪ Press briefly to store an image if the image is currently frozen ▪ Press and hold down for a few seconds to store without freezing the image ▪ Press to move between panes in some dialog boxes ▪ Press to leave freeze mode and go to live mode
C	▪ Press to leave dialog boxes without changing any settings ▪ Press twice to leave edit mode ▪ If the camera is in manual adjust mode, press to change the function of the joystick to level (up/down) and span (left/right)

Button	Comments
Joystick	■ Press to display the menu system ■ Press to exit the menu system ■ Press to confirm selections and leave dialog boxes ■ Press to select measurement markers ■ Move up/down or left/right to navigate in menus, dialog boxes, and on the screen ■ Move up/down or left/right to move or resize measurement markers ■ Move up/down to change focus and left/right to zoom ■ If the camera is in manual adjust mode, press C to change the function of the joystick to level (up/down) and span (left/right)
+/–	Programmable functions: ■ **Focus** ■ **Zoom** ■ **Level** ■ **Span**
F1	Programmable functions: ■ **None** ■ **Adjust once** ■ **Auto focus** ■ **Reverse palette** ■ **Next palette** ■ **Visual/IR** ■ **Update ref temp**
F2	Programmable functions: ■ **None** ■ **Adjust once** ■ **Auto focus** ■ **Reverse palette** ■ **Next palette** ■ **Visual/IR** ■ **Update ref temp**
Button for Laser LocatIR	Press to switch on Laser LocatIR

7.3 Autofocus

To focus the camera using the autofocus feature, press and hold down the **A** button for one second.

NOTE: Please note the following:

- The area that the camera uses when autofocusing is a 80 × 60 pixel box, centered vertically and horizontally on the screen
- The camera will have difficulties autofocusing when the image has low contrasts between different areas
- You should keep the camera steady when autofocusing

7.4 IrDA infrared communication link

If you have access to a PDA or a laptop computer equipped with an IrDA infrared communication link, you can upload text comment files (*.tcf) to the internal flash memory in ThermaCAM™ P60.

Step	Action
1	ThermaCAM Reporter 7.0 – a reporting software from FLIR Systems – provides a user-friendly interface to create text comment files. Create your text comment file using this software, but save the file to Desktop as a pure text file (*.txt) instead of as a text comment file (*.tcf). **NOTE:** For more information about using the text comment editor in ThermaCAM Reporter 7.0, consult any of the following manuals: ▪ ThermaCAM™ Reporter Pro 7.0 Manuel d’utilisation (1 557 790) ▪ ThermaCAM™ Reporter Pro 7.0 Bedienungsanleitung (1 557 792) ▪ ThermaCAM™ Reporter Pro 7.0 Manual del usuario (1 557 794) ▪ ThermaCAM™ Reporter Pro 7.0 Manuale dell'operatore (1 557 796) ▪ ThermaCAM™ Reporter Pro 7.0 User's Manual (1 557 788)
2	Transfer the *.txt file to your PDA (or laptop, if you created the file on a desktop computer).
3	Point to **Text comment** on the **File** menu in ThermaCAM™ P60 and press the joystick.
4	Upload the file from the PDA (or laptop) to ThermaCAM™ P60. A dialog box will confirm receipt of the file.

7.5 Camera status LCD

The camera status LCD on the left side of the camera displays information about battery status, communication status, memory status *etc*.

10346003;2

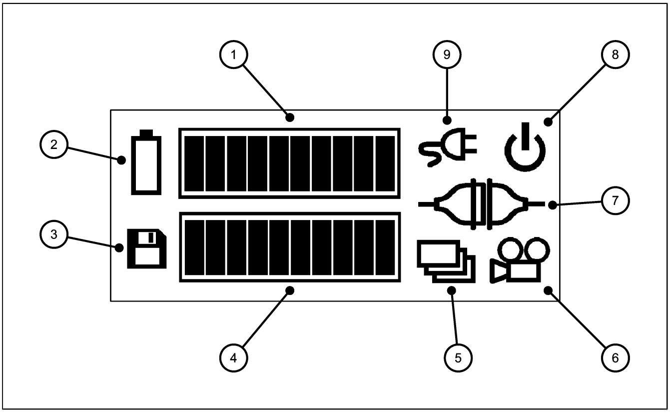


Figure 7.8 Camera status LCD

Figure 7.9 Camera status LCD – explanations

Callout	Comments
1	Battery status bar. The frame around the battery status bar is switched on when a battery is inserted. ▪ All segments switched on = fully charged battery ▪ All segments switched off = empty battery or no battery inserted
2	Battery indicator. Switched on if a battery is inserted, flashing if the battery is being charged internally.
3	CompactFlash card indicator. Switched on if a CompactFlash card is inserted.
4	CompactFlash status bar: ▪ All segments switched on = the card is empty ▪ All segments switched off = the card is full
5	Not implemented
6	Burst recording indicator. Switched on during burst recording.
7	Communication indicator. Switched on when a communication link is active.
8	Power indicator: ▪ Both segments switched on when the camera is switched on ▪ Both segments switched off when the camera is switched off ▪ The outer segment flashing when the camera is in ‘deep sleep’
9	External power indicator. Switched on when the camera is externally powered.

7.6 Laser LocatIR

The ThermaCAM™ P60 infrared camera features a laser pointer located at the front of the camera handle. To display the laser dot, press the Laser LocatIR button on left side of the handle. The laser dot will appear approx. 91 mm/3.6" above the target.

NOTE: Please note the following:

- A laser icon appears on the screen when the Laser LocatIR is switched on.
- Since the distance between the laser beam and the image center will vary by the target distance, Laser LocatIR should only be used as an aiming aid. Always check the LCD to make sure the camera captures the desired target.
- Do not look directly into the laser beam.
- When not in use, the Laser LocatIR should always be protected by the lens cap.

10376403;2

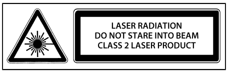


Figure 7.10 Wavelength: 635 nm. Max. output power: 1 mW. This product complies with 21 CFR 1040.10 and 1040.11 except for deviations pursuant to Laser Notice No. 50, dated July 26th, 2001

10395103;3

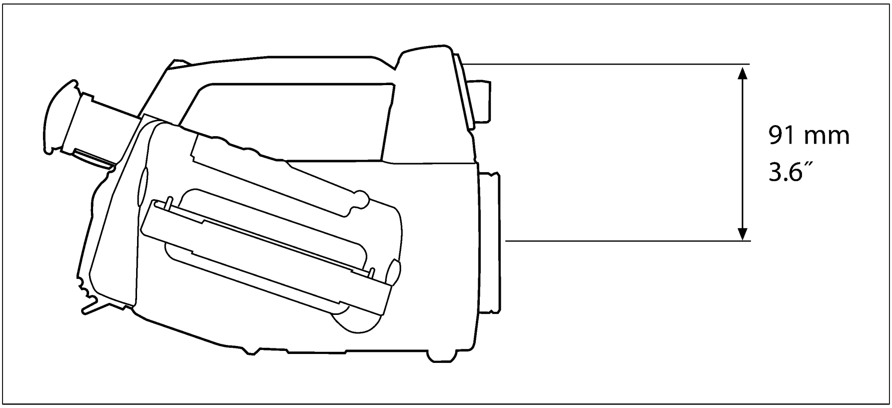


Figure 7.11 Distance between the laser beam and the image center

7.7 Visual camera

The ThermaCAM™ P60 infrared camera features a visual camera located at the front of the camera handle. The visual camera has no motorized focus and you will need to occasionally focus the camera by rotating the lens manually.

8 Camera program

8.1 Screen objects

8.1.1 Result table

The results of measurement markers are displayed in a result table in the top right-hand corner of the screen.

Figure 8.1 Explanation of measurement markers appearing in the result table

Icon	Explanation
	Spot
1	Box 1, maximum temperature
1	Box 1, minimum temperature
1	Box 1, average temperature
1	Circle 1, maximum temperature
1	Circle 1, minimum temperature
1	Circle 1, average temperature
1	Line 1, maximum temperature
1	Line 1, minimum temperature
1	Line 1, average temperature
1	Line 1, cursor temperature
1	Isotherm 1, above
1	Isotherm 1, below
1	Isotherm 1, interval
1	Isotherm 1, dual above
1	Isotherm 1, dual below
XXX–YYY	Difference calculation
R	Camera reference temperature

8.1.2 Status bar

10388403;2

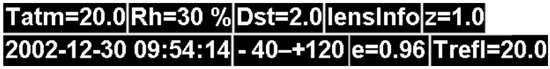


Figure 8.2 Status bar, showing atmospheric temperature, relative humidity, distance to target, zoom factor, date & time, temperature range, emissivity, and reflected ambient temperature.

Information about an image and the current conditions appear on the first and second bottom lines of the screen. If text comments are attached to an image file, they are displayed above these two lines.

NOTE: If you enter an emissivity value less than 0.30 the emissivity box will begin flashing to remind you that this value is unusually low.

8.1.3 Temperature scale

10388503;2

Figure 8.3 Temperature scale

The temperature scale is displayed on the right-hand side of the screen. The scale shows how the colors are distributed along the various temperatures in the image, with high temperatures at the upper end and low temperatures at the lower end.

8.1.4 System messages

8.1.4.1 Status messages

Status messages are displayed at the bottom of the screen, or in the top left part of the screen. Here you will find information about the current status of the camera, *etc.*

Figure 8.4 Status messages – a few examples

Message	Explanation
Frozen	Message is displayed when the image is frozen.

Message	Explanation
Manual	Message is displayed when the camera is currently in manual adjust mode.
Restarting	Message is displayed when the software is restarted, *i.e.* after **Factory default**.
Saving as	Message is displayed while an image is being saved.

8.1.4.2 Warning messages

Warning messages are displayed in the center of the screen. Here you will find important information about battery status, *etc.*

Figure 8.5 Critical camera information – a few examples

Message	Explanation
Battery low	The battery level is below a critical level.
Shutting down	The camera will be switched off immediately.
Shutting down in 2 seconds	The camera will be switched off in 2 seconds.

8.2 Menu system

8.2.1 Navigating in the menu system

- Press the joystick to display the horizontal menu bar
- Press the joystick to confirm selections in menus and dialog boxes
- Press the **C** button to exit the menu system
- Press the **C** button to cancel selections in menus and dialog boxes
- Move the joystick up/down to move up/down in menus, submenus and dialog boxes
- Move the joystick right/left to move right/left in menus and submenus, and to change values in dialog boxes

8.2.2 File menu

8.2.2.1 *Images*

10565703;1

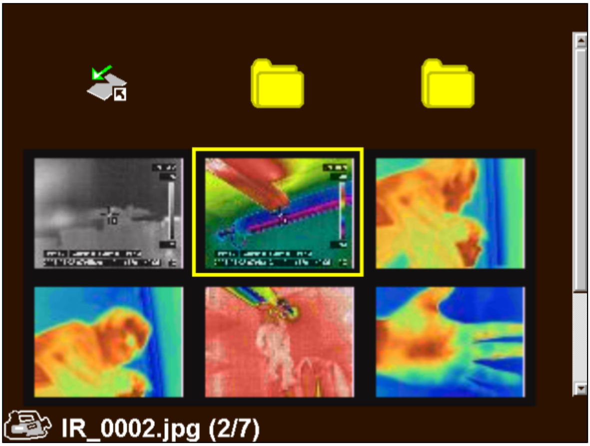


Figure 8.6 **Images** folder

Point to **Images** and press the joystick to display a thumbnail view of the files on the CompactFlash® card, or in the internal camera memory. The following files are displayed:

- infrared images
- visual images
- *.avi files (DV-AVI files captured using burst recording)
- *.etf files (emissivity table files)
- *.tcf files (text comment files)

10565803;1

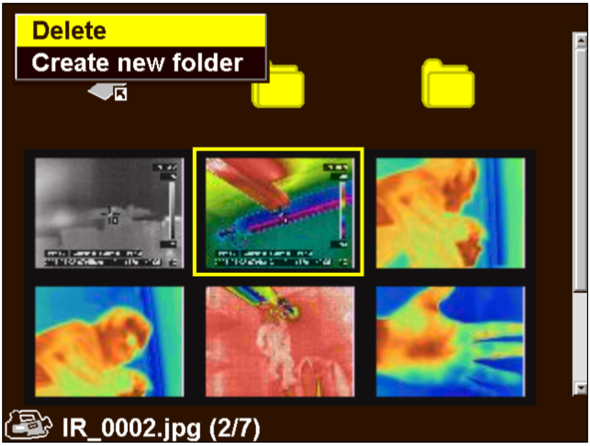


Figure 8.7 **Images** folder, showing the context menu

In the **Images** folder you can do the following:

- Open an image by selecting the image using the joystick, then pressing the joystick
- Create a new folder by selecting an image, then pressing and holding down the joystick, and selecting **Create new folder**
- Delete an image by selecting the image, then pressing and holding down the joystick, and selecting **Delete**
- Move between the internal memory and the CompactFlash® card

8.2.2.2 Save

Point to **Save** and press the joystick to save the displayed image to the internal flash memory, or the CompactFlash card.

SEE ALSO: For more information about saving images, and using voice and text comments, see section 8.2.5.3 – Save on page 70, 8.2.2.6 – Voice comment on page 45and 8.2.2.7 – Text comment on page 46.

8.2.2.3 Copy to card

Point to **Copy to card** to copy the contents of the internal image folder to a automatically created folder on a CompactFlash® card

8.2.2.4 Periodic save

10389603;2

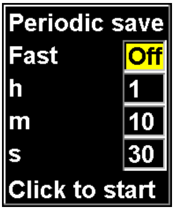


Figure 8.8 **Periodic save** dialog box

Point to **Periodic save** and press the joystick to display the **Periodic save** dialog box. Using the periodic save feature, you can save a number of images, at a certain selectable periodicity, to the internal flash memory or the CompactFlash card. Together with the images, all the current conditions will be saved.

Figure 8.9 Explanations of the **Periodic save** dialog box

Task	Action	Comment
Setting the periodicity	Move the joystick left/right	The periodicity can be set from 10 seconds up to 24 hours. Select **Fast** → **On** for shortest possible time interval (< 10 seconds).
Starting the recording	Press the joystick	
Stopping the recording	Press the joystick again **NOTE:** Images will be stored sequentially in the current directory. If the recording is stopped and then started again the new images will be added at the end of the previous sequence in the same directory.	

8.2.2.5 Burst recording

NOTE: Depending on your camera configuration, this feature may be an extra option.

Point to **Burst recording** and press the joystick to display the **Burst recording** dialog box. Using the burst recording feature, you can:

- record and save a sequence of frames at a very high speed
- save specific frames as infrared images
- play back the sequence backward and forward
- set stop and start frames in a sequence to save a part of the sequence
- choose between looped or linear recording mode

10389703;2

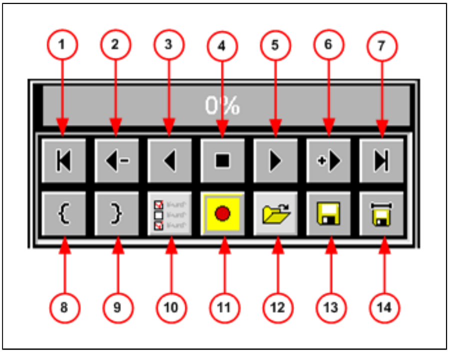
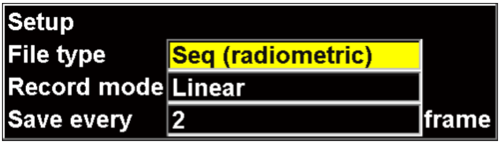


Figure 8.10 **Burst recording** toolbar and progress bar

Figure 8.11 Explanations of the **Burst recording** toolbar

Callout	Explanation
1	Go to beginning of frame sequence
2	Go to previous frame in the frame sequence
3	Play back the frame sequence backward
4	Stop the recording or the playback of the frame sequence
5	Play back the frame sequence forward
6	Go to the next frame in the frame sequence
7	Go to the end of the frame sequence
8	Set start frame for saving of the frame sequence
9	Set stop frame for saving of the frame sequence

Callout	Explanation
10	■ As **File type**, select **AVI (non-radiometric)** or **SEQ (radiometric)**. ■ As **Record mode**, select **Circular** or **Linear**. **Circular** means that the recording will automatically start over when the internal RAM memory is full. This may be useful when it is extremely important that the beginning of an event is recorded, and it is difficult to start the recording at the exact time. **Linear** means that the recording will start when you click button 11 and stop when the internal RAM memory is full (unless the recording is stopped manually). ■ Set the frame rate by specifying a number in the bottom row. For example, setting the frame rate to 2 means 25 or 30 Hz, depending on TV system. **NOTE:** The AVI recording will be saved as a DV-AVI file. 10565303;1 
11	Record a frame sequence
12	Open a saved frame sequence (a *.seq file or an *.avi file)
13	Save the current frame as an IR image
14	Open a saved frame sequence (a *.seq file or an *.avi file)

8.2.2.6 Voice comment

10389803;2

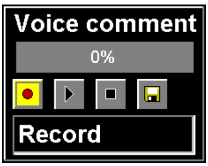


Figure 8.12 Voice comment dialog box

Point to **Voice comment** and press the joystick to display the **Voice comment** dialog box. A progress bar in the dialog box will indicate the progress of the voice recording. Using the voice comment feature, you can:

- listen to a recorded comment, make a pause, and then continue
- record a new comment, make a pause, and then continue
- edit a recorded comment, *i.e.* listen and/or add a comment at the end of the recorded comment
- overwrite an existing recording

Figure 8.13 Explanations of the **Voice comment** dialog box

Task	Action
Recording a new voice comment, using the headset	Move the joystick to select the **Record** button and then press the joystick.
Stopping the recording	Move the joystick to select the **Stop** button and then press the joystick.
Listening to a voice comment, using the headset	Move the joystick to select the **Play** button and then press the joystick.
Saving the current voice comment	Move the joystick to select the **Save** button and then press the joystick, or press the S button.

8.2.2.7 *Text comment*

Point to **Text comment** and press the joystick to display the **Text comment** dialog box. Using the text comment feature, you can annotate images by using a file with predefined text strings. Such a file can be created and edited in FLIR Systems's PC software – for example, in ThermaCAM Reporter 7.0.

The concept of text comments is based on two important definitions – *label* and *value*. The following examples explain what the difference between the two definitions is:

Figure 8.14 Definitions of label and value

Label (examples)	Value (examples)
Company	**FLIR Systems**
Building	**Workshop**
Section	**Room 1**
Equipment	**Tool 1**
Recommendation	**Repair**

Figure 8.15 Creating a text comment

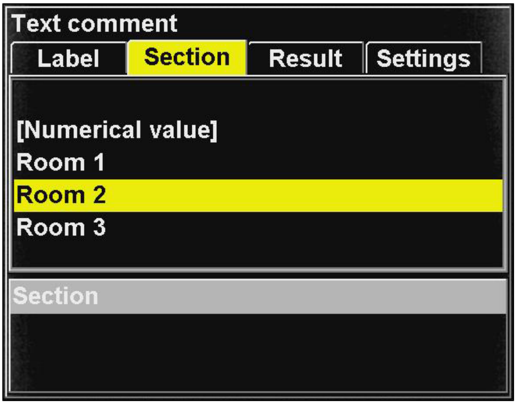
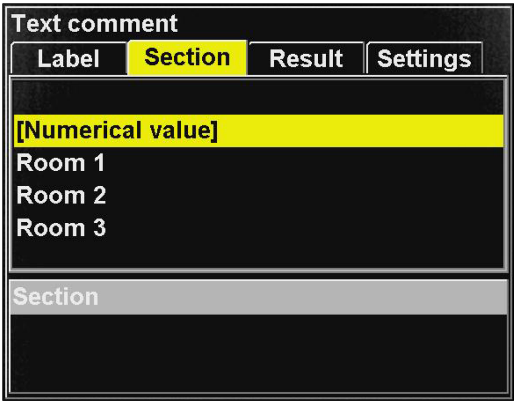
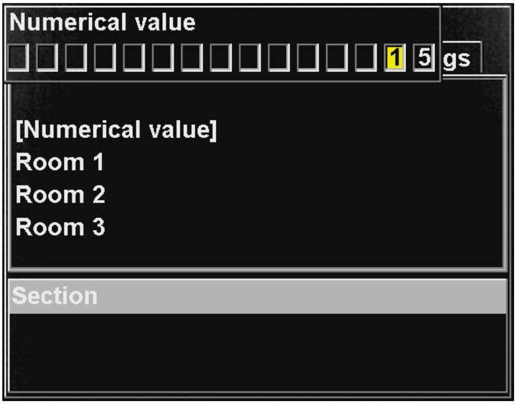
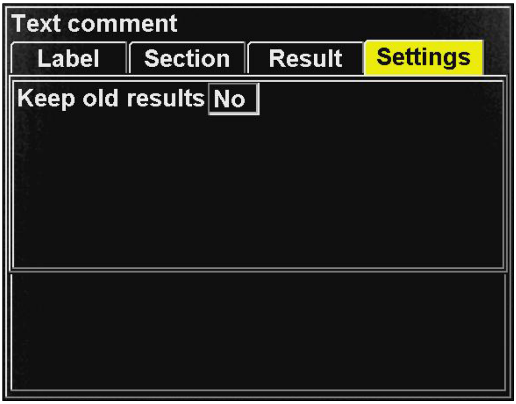
Step	Action
1	Point to **Text comment** on the **File** menu and press the joystick. A dialog box with a number of tabs will appear on the screen. Move the joystick up/down to select a label on the first tab, and then press the joystick. 10566003;1 
2	Move the joystick up/down to select a value on the second tab, and press the joystick. 10566103;1 
3	To see the complete result, move the joystick to the right to go to the third tab.
4	Press the S button to save the text comment and leave the dialog box.

Figure 8.16 Creating a numerical value to be used in a text comment

Step	Action
1	Point to **Text comment** on the **File** menu and press the joystick. A dialog box with four tabs will appear on the screen. Move the joystick up/down to select a label on the first tab, and then press the joystick. 10566003;1 
2	To specify a numerical value that you can select on the first tab, select **Numerical value** and press the joystick. 10566203;1 

Step	Action
3	Move the joystick up/down and left/right to specify a numerical value. Spaces before and after the value will be deleted. 10566303;1 
4	To keep the text comment for future use, select **Yes** on the **Settings** tab. 10566403;1 
5	To include the numerical value in your text comment, go back to the first tab and select the value.
6	Press the S button to save the text comment and leave the dialog box.

NOTE: Please note the following:

- Using the text comments command requires that a CompactFlash card with the appropriate *.tcf file is inserted into the camera, or that the file is stored in the camera's internal flash memory. To make the text strings load, it is important that the *.tcf file is saved on image root level or in the directory where the images are saved on the CompactFlash card. If the images are saved in the internal flash memory, the *.tcf file should be in the same directory as the images.
- For more information about using the text comment editor in ThermaCAM Reporter 7.0, consult any of the following manuals:
  - ThermaCAM Reporter 7.0 Bedienungsanleitung (1 557 792)
  - ThermaCAM Reporter 7.0 Manuel d'utilisation (1 557 790)
  - ThermaCAM Reporter 7.0 Manual del usuario (1 557 794)
  - ThermaCAM Reporter 7.0 Manuale dell'operatore (1 557 796)
  - ThermaCAM Reporter 7.0 Operator's manual (1 557 788)

8.2.3 Analysis menu

8.2.3.1 Edit mode

Point to **Edit mode** and press the joystick to enter the *edit mode* of the camera. When the camera is in *edit mode* you can select, move, and resize measurement markers as well as changing levels of isotherms etc. You leave edit mode by pressing the C button.

8.2.3.2 Add spot

Point to **Add spot** and press the joystick to add a spot. A spot will now be displayed on the screen. Press and hold down the joystick for one second when the spot is selected to display a shortcut menu.

10390103;2

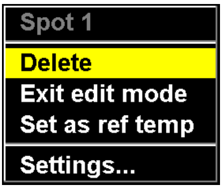


Figure 8.17 Shortcut menu for **Spot**

Figure 8.18 Explanations of the shortcut menu for **Spot**

Command	Explanation
Delete	Point to **Delete** and press the joystick to delete the spot.
Exit edit mode	Point to **Exit edit** mode and press the joystick to exit the edit mode.
Set as ref temp	Point to **Set as ref temp** and press the joystick to use the spot temperature as the reference temperature.

Command	Explanation
Settings	See below.

Point to **Settings** and press the joystick to display a **Spot settings** dialog box where you can change the settings for the spot.

10390203;2

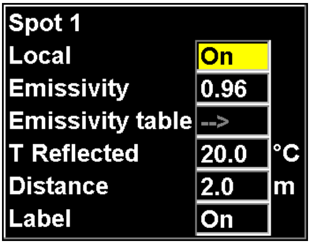


Figure 8.19 **Spot** dialog box

Figure 8.20 Explanations of the **Spot** dialog box

Label	Value	Comments
Local	▪ **On** ▪ **Off**	Select **On** to set the emissivity, the reflected temperature, and the distance for this spot only. Selecting **On** will also assign an asterisk to the measurement marker's label.
Emissivity	User-defined (0.01–1.00)	You can set the **Emissivity** if **Local** is enabled. If not, this option will be shaded. **NOTE:** If you enter an emissivity value less than 0.30 the emissivity box will begin flashing to remind you that this value is unusually low.

Label	Value	Comments
Emissivity table	User-defined	Press the button to the right of **Emissivity table** to display an emissivity table on the screen. You can use this emissivity table to find emissivities for a number of different materials. An emissivity table can be created and edited in FLIR Systems's PC software. **NOTE:** The emissivity file can be stored at root level or at directory level. However, the camera software prioritizes files that are stored at directory level and the directory has to be selected in order to store the emissivity file in the camera memory. If the camera software does not find an emissivity file at directory level, it searches for similar files at root level and saves those instead.
T Reflected	User-defined	You can set **T Reflected** if **Local** is enabled. If not, this option will be shaded.
Distance	User-defined	You can set **Distance** if **Local** is enabled. If not, this option will be shaded.
Label	■ **On** ■ **Off**	Select **On** to assign a label to the measurement marker (a small box with a number).

8.2.3.3 Add box

Point to **Add box** and press the joystick to add a box. A box will now appear on the screen. Press and hold down the joystick for one second when the box is selected to display a shortcut menu.

Publ. No. 1 557 945 Rev. a43 – ENGLISH (EN) – April 6, 2004

10390303;2

Figure 8.21 Shortcut menu for **Box**

Figure 8.22 Explanations of the shortcut menu for **Box**

Command	**Explanation**
Delete	Point to **Delete** and press the joystick to delete the box.
Exit edit mode	Point to **Exit edit** mode and press the joystick to exit the edit mode.
Set as ref temp	Point to **Set as ref temp** and press the joystick to use the box temperature as the reference temperature.
Max	Point to **Max** and press the joystick to display the *maximum* temperature of the box
Min	Point to **Min** and press the joystick to display the *minimum* temperature of the box
Avg	Point to **Avg** and press the joystick to display the *average* temperature of the box.
Settings	See below.

Point to **Settings** and press the joystick to display a **Box settings** dialog box where you can change the settings for the box.

10390403;2

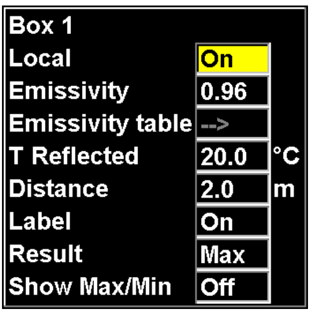


Figure 8.23 **Box** dialog box

Figure 8.24 Explanations of the **Box** dialog box

Label	Value	Comments
Local	■ **On** ■ **Off**	Select **On** to set the emissivity, the reflected temperature, and the distance for this box only. Selecting **On** will also assign an asterisk to the measurement marker's label.
Emissivity	User-defined (0.01–1.00)	You can set the **Emissivity** if **Local** is enabled. If not, this option will be shaded. **NOTE:** If you enter an emissivity value less than 0.30 the emissivity box will begin flashing to remind you that this value is unusually low.
Emissivity table	User-defined	Press the button to the right of **Emissivity table** to display an emissivity table on the screen. You can use this emissivity table to find emissivities for a number of different materials. An emissivity table can be created and edited in FLIR Systems's PC software. **NOTE:** The emissivity file can be stored at root level or at directory level. However, the camera software prioritizes files that are stored at directory level and the directory has to be selected in order to store the emissivity file in the camera memory. If the camera software does not find an emissivity file at directory level, it searches for similar files at root level and saves those instead.
T Reflected	User-defined	You can set **T Reflected** if **Local** is enabled. If not, this option will be shaded.

Label	Value	Comments
Distance	User-defined	You can set **Distance** if **Local** is enabled. If not, this option will be shaded.
Label	▪ **On** ▪ **Off**	Select **On** to assign a label to the measurement marker (a small box with a number).
Result	▪ **Min** ▪ **Max** ▪ **Avg**	To change how the measurement results will be displayed, select **Max**, **Min**, or **Avg**.
Show Max/Min	▪ **On** ▪ **Off**	To display two moving cursors inside the box, continuously indicating the maximum and minimum temperature, select **On**.

8.2.3.4 Add circle

Point to **Add circle** and press the joystick to add a circle. A circle will now appear on the screen. Press and hold down the joystick for one second when the circle is selected to display a shortcut menu.

10390503;2

Figure 8.25 Shortcut menu for **Circle**

Figure 8.26 Explanations of the shortcut menu for **Circle**

Command	Explanation
Delete	Point to **Delete** and press the joystick to delete the circle.
Exit edit mode	Point to **Exit edit** mode and press the joystick to exit the edit mode.
Set as ref temp	Point to **Set as ref temp** and press the joystick to use the circle temperature as the reference temperature.

Command	Explanation
Max	Point to **Max** and press the joystick to display the *maximum* temperature of the circle.
Min	Point to **Min** and press the joystick to display the *minimum* temperature of the circle.
Avg	Point to **Avg** and press the joystick to display the *average* temperature of the circle
Settings	See below.

Point to **Settings** and press the joystick to display a **Circle settings** dialog box where you can change the settings for the circle.

10390603;2

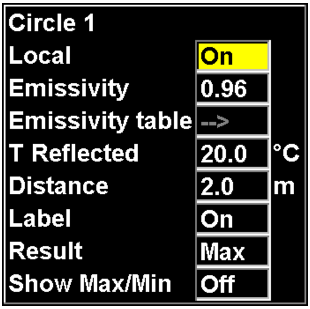


Figure 8.27 **Circle** dialog box

Figure 8.28 Explanations of the **Circle** dialog box

Label	Value	Comments
Local	■ **On** ■ **Off**	Select **On** to set the emissivity, the reflected temperature, and the distance for this circle only. Selecting **On** will also assign an asterisk to the measurement marker's label.
Emissivity	User-defined (0.01–1.00)	You can set the **Emissivity** if **Local** is enabled. If not, this option will be shaded. **NOTE:** If you enter an emissivity value less than 0.30 the emissivity box will begin flashing to remind you that this value is unusually low.

Label	**Value**	**Comments**
Emissivity table	User-defined	Press the button to the right of **Emissivity table** to display an emissivity table on the screen. You can use this emissivity table to find emissivities for a number of different materials. An emissivity table can be created and edited in FLIR Systems's PC software. **NOTE:** The emissivity file can be stored at root level or at directory level. However, the camera software prioritizes files that are stored at directory level and the directory has to be selected in order to store the emissivity file in the camera memory. If the camera software does not find an emissivity file at directory level, it searches for similar files at root level and saves those instead.
T Reflected	User-defined	You can set **T Reflected** if **Local** is enabled. If not, this option will be shaded.
Distance	User-defined	You can set **Distance** if **Local** is enabled. If not, this option will be shaded.
Label	■ **On** ■ **Off**	Select **On** to assign a label to the measurement marker (a small box with a number).
Result	■ **Min** ■ **Max** ■ **Avg**	To change how the circle displays the measurement results, select **Max**, **Min**, or **Avg**.
Show Max/Min	■ **On** ■ **Off**	To display two moving cursors inside the circle, continuously indicating the maximum and minimum temperature, select **On**.

8.2.3.5 Add line

Point to **Add line** and press the joystick to add a line. A line will now appear on the screen. Press and hold down the joystick for one second when the line is selected to display a shortcut menu.

10390703;2

Figure 8.29 Shortcut menu for **Line**

Figure 8.30 Explanations of the shortcut menu for **Line**

Command	Explanation
Delete	Point to **Delete** and press the joystick to delete the line.
Exit edit mode	Point to **Exit edit** mode and press the joystick to exit the edit mode.
Show profile	Point to **Show profile** and press the joystick to display a profile window. The profile window displays the different temperature levels along the line as a graph.
Set as ref temp	Point to **Set as ref temp** and press the joystick to use the line temperature as the reference temperature.
Cursor	Point to **Cursor** and press the joystick to display a cursor that you can move along the line.
Max	Point to **Max** and press the joystick to display the *maximum* temperature along the line.
Min	Point to **Min** and press the joystick to display the *minimum* temperature along the line.
Avg	Point to **Avg** and press the joystick to display the *average* temperature along the line.
Settings	See below.

Point to **Settings** and press the joystick to display a **Line settings** dialog box where you can change the settings for the line.

10390803;2

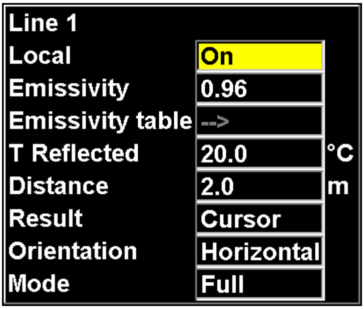


Figure 8.31 **Line** dialog box

Figure 8.32 Explanations of the **Line** dialog box

Label	Value	Comments
Local	■ **On** ■ **Off**	Select **On** to set the emissivity, the reflected temperature, and the distance for this line only. Selecting **On** will also assign an asterisk to the measurement marker’s label.
Emissivity	User-defined (0.01–1.00)	You can set the **Emissivity** if **Local** is enabled. If not, this option will be shaded. **NOTE:** If you enter an emissivity value less than 0.30 the emissivity box will begin flashing to remind you that this value is unusually low.

Label	Value	Comments
Emissivity table	User-defined	Press the button to the right of **Emissivity table** to display an emissivity table on the screen. You can use this emissivity table to find emissivities for a number of different materials. An emissivity table can be created and edited in FLIR Systems's PC software. **NOTE:** The emissivity file can be stored at root level or at directory level. However, the camera software prioritizes files that are stored at directory level and the directory has to be selected in order to store the emissivity file in the camera memory. If the camera software does not find an emissivity file at directory level, it searches for similar files at root level and saves those instead.
T Reflected	User-defined	You can set **T Reflected** if **Local** is enabled. If not, this option will be shaded.
Distance	User-defined	You can set **Distance** if **Local** is enabled. If not, this option will be shaded.
Result	▪ **Min** ▪ **Max** ▪ **Avg**	Point to **Max**, **Min** or **Avg** and press the joystick to change how the line displays the measurement results
Orientation	▪ **Horizontal** ▪ **Vertical**	Point to **Horizontal** or **Vertical** and press the joystick to make the line horizontal or vertical.

Label	Value	Comments
Mode	■ **Full** ■ **Aligned**	Point to **Full** and press the joystick to make the line be of the same width or height as the screen. Point to **Aligned** and press the joystick to make the line be of the same width or height as the profile box.

8.2.3.6 Add isotherm

The isotherm command colors all pixels with a temperature above, below or between one or more preset temperature levels.

10390903;2

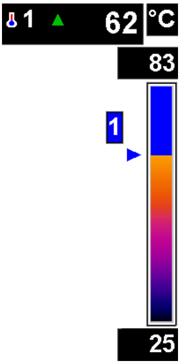


Figure 8.33 Temperature scale showing an isotherm set to above +62 °C

Point to **Add isotherm** and press the joystick to add an isotherm. An isotherm has now be added to your image. Press and hold down the joystick for one second when the isotherm (in the temperature scale) is selected to display a shortcut menu.

10391003;2

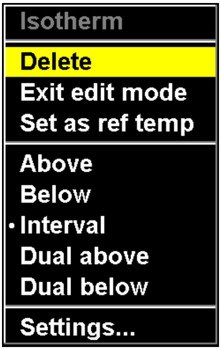


Figure 8.34 Shortcut menu for **Isotherm**

Figure 8.35 Explanations of the **Isotherm** shortcut menu

Command	Explanation
Delete	Point to **Delete** and press the joystick to delete the isotherm.
Exit edit mode	Point to **Exit edit** mode and press the joystick to exit the edit mode.
Set as ref temp	Point to **Set as ref temp** and press the joystick to use the isotherm temperature as the reference temperature.
Above	All pixels with a temperature higher than a set temperature will be colored with the same preset isotherm color.
Below	All pixels with a temperature lower than a set temperature will be colored with the same preset isotherm color.
Interval	All pixels with a temperature within the set interval will be colored with the same preset isotherm color.
Dual Above	All pixels in two consecutive temperature ranges above a set temperature will be colored with two different preset isotherm colors.
Dual Below	All pixels in two consecutive temperature ranges below a set temperature will be colored with two different preset isotherm colors.
Settings	See below

Point to **Settings** and press the joystick to display an **Isotherm settings** dialog box where you can change the settings for the isotherm.

10397403;2

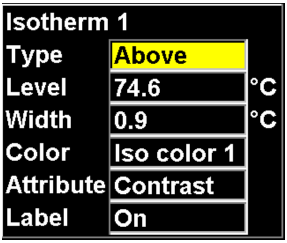


Figure 8.36 **Isotherm** dialog box

Figure 8.37 Explanations of the **Isotherm** dialog box

Label	Value	Comments
Type	▪ **Interval** ▪ **Above** ▪ **Below** ▪ **Dual Above** ▪ **Dual Below**	**SEE:** For an explanation of isotherm types, see above.
Level	User-defined	The temperature level in degrees Celsius (°C) or degrees Fahrenheit (°F).
Width	User-defined	The temperature width in degrees Celsius (°C) or degrees Fahrenheit (°F).
Color	Configuration-dependent	The colors used for the isotherm.
Attribute	▪ **Transparent** ▪ **Solid**	Selecting **Transparent** will add some transparency to an isotherm color, making it easier for you to see objects through the color. To make the isotherm colors appear solid, select **Solid**.
Label	▪ **On** ▪ **Off**	Selecting **On** will assign a label to the measurement marker (a small box with a number).

8.2.3.7 Add diff

Point to **Add diff** and press the joystick to add a difference calculation, which will appear in the result table.

SEE ALSO: For more information about difference calculations, see section 8.2.5.2 – Difference on page 69.

8.2.3.8 Ref temp

10391403;2

Figure 8.38 Reference temperature dialog box

The reference temperature can be used when the camera calculates temperature differences

- Point to **Ref temp** and press the joystick to set the temperature
- To change the temperature, move the joystick up/down
- Press the joystick to leave the dialog box

8.2.3.9 Remove all

Point to **Remove all** and press the joystick to remove all measurement functions and markers from the screen.

8.2.3.10 Obj par

10439203;1

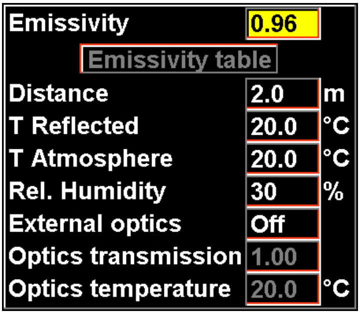


Figure 8.39 Object Parameters dialog box

You use this command to set the object parameters **Emissivity**, **Distance**, **T Reflected**, **T Atmosphere**, **Rel humidity**, **External optics**, **Optics transmission**, and **Optics temperature.** The parameters are selected by moving the joystick up/down and set by moving the joystick left/right. These parameters settings will be used by all measurement functions that have not been set locally.

Click **Emissivity table** to display an emissivity table on the screen. You can use this emissivity table to find emissivities for a number of different materials. An emissivity table can be created and edited in FLIR Systems's PC software.

Publ. No. 1 557 945 Rev. a43 – ENGLISH (EN) – April 6, 2004

NOTE: Please note the following:

- The emissivity file can be stored at root level or at directory level. However, the camera software prioritizes files that are stored at directory level and the directory has to be selected in order to store the emissivity file in the camera memory. If the camera software does not find an emissivity file at directory level, it searches for similar files at root level and saves those instead.
- If you enter an emissivity value less than 0.30 the emissivity box will begin flashing to remind you that this value is unusually low.
- The transmission factor is applied to the signal and not to the temperature

SEE ALSO: For more information about object parameters, see section 15 – Thermographic measurement techniques on page 110.

8.2.3.11 *Deactivate local par.*

Point to **Deactivate local par.** and press the joystick to delete all locally set parameters. Locally set parameters are the parameters you set in *e.g.* the **Spot settings** dialog box.

8.2.4 Image menu

8.2.4.1 *Visual/IR*

Point to **Visual/IR** and press the joystick to switch between *visual* mode and *IR* mode.

8.2.4.2 *Freeze/Live*

Point to **Freeze/Live** and press the joystick to switch between *freeze* image mode and *live* image mode. It has the same effect as briefly pressing the **S** button.

8.2.4.3 *Range*

10391903;4

Figure 8.40 **Range** dialog box

Point to **Range** and press the joystick to display a dialog box where you can set the range.

8.2.4.4 *Level/Span*

Point to **Level/Span** and press the joystick to manually change *level* and *span*. The level command can be regarded as the *brightness*, while the span command can be regarded as the *contrast*.

- Move the joystick up/down to change the level (indicated by an arrow pointing upwards or downwards in the temperature scale)
- Move the joystick left/right to change the span (indicated by two arrows pointing away from each other or towards each other)

10392103;3

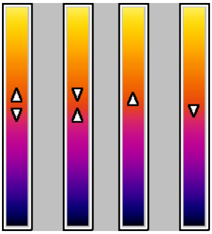


Figure 8.41 Symbols in the temperature scale, indicating (1) increasing span; (2) decreasing span; (3) increasing level, and (4) decreasing level

SEE ALSO: For more information about object parameters, see section 15 – Thermographic measurement techniques on page 110.

8.2.4.5 Manual adjust / Continuous adjust

- Point to **Manual adjust** and press the joystick to put the camera in manual adjust mode. You can now change level and span by first pressing the **C** button repeatedly (to change the function of the joystick to level/span), and then change level or span by moving the joystick up/down and left/right, respectively
- Point to **Continuous adjust** and press the joystick to put the camera in automatic mode, continuously optimizing the image for best level and span

SEE ALSO: For more information about the **Level/Span** command, see section 8.2.4.4 – Level/Span on page 65.

8.2.4.6 Palette

10392003;2

Figure 8.42 Palette dialog box

Point to **Palette** and press the joystick to display a dialog box where you can change the color palette.

Figure 8.43 Explanations of the **Palette** dialog box

Label	**Value**	**Comments**
Palette	Configuration-dependent	Move the joystick left/right to change the palette.
Inverted	▪ **Yes** ▪ **No**	Move the joystick left/right to reverse the current palette.

Custom palettes (*.pal) can be used by the camera. For more information about how to create custom palettes, contact FLIR Systems.

8.2.4.7 Hide graphics

Point to **Hide graphics** and press the joystick to hide all on-screen graphics (*e.g.* result table, status bar *etc.*). To display the graphics again, press the joystick or the C button.

8.2.4.8 Add visual marker

You can add a visual marker to an image when the camera is in visual mode by pointing to **Add visual marker** and press the joystick. By moving the joystick up/down or left/right you can move the marker on the image and place it where you want it to be.

8.2.5 Setup menu

NOTE: Depending on camera configuration, some menu items on the **Setup** menu may be displayed in a different order, or on a submenu.

8.2.5.1 Image

10439803;1

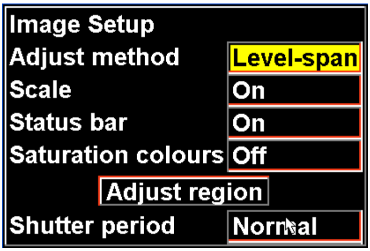


Figure 8.44 **Image Setup** dialog box

Figure 8.45 Explanations of the **Image Setup** dialog box

Label	Value	Comments
Adjust method	▪ **Level** ▪ **Level-span** ▪ **Histogram**	Move the joystick left/right to change the adjust method. These settings influence the image quality and different settings may be suitable for different types of images and/or applications.
Scale	▪ **On** ▪ **Off**	Move the joystick left/right to enable or disable the scale.
Status bar	▪ **On** ▪ **Off**	Move the joystick left/right to enable or disable the status bar.

Label	Value	Comments
Saturation colors	▪ **On** ▪ **Off**	Move the joystick left/right to enable or disable the saturation colors. If **On** is selected the areas that contain temperatures outside the present level/span settings are colored with the saturation colors. The saturation colors contain an 'overflow' color and an 'underflow' color. There is also a third red saturation color that marks everything saturated by the detector indicating that the range should be changed.
Adjust region		Press the **Adjust region** button to display a region on the screen that will be used when autoadjusting the camera.

Label	Value	Comments
Shutter period	▪ **Normal** ▪ **Short** ▪ **Off**	Press the joystick left/right to change the shutter period, or switch off the shutter. **NOTE:** Please note the following: ▪ Although the shutter period works independently of other functions described in this publication, FLIR Systems recommends that **Short** is selected when using the camera for detection of face temperature. ▪ Selecting **Normal** will calibrate the camera at least every 15th minute, while selecting **Short** will calibrate the camera at least every 3rd minute. ▪ If the shutter is switched off, a symbol (*) will prefix the result at the time a shutter sequence should have taken place, thus indicating uncertainty in the measurement result.

8.2.5.2 *Difference*

10393203;2

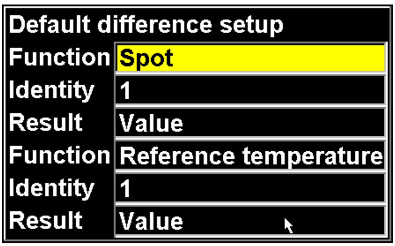


Figure 8.46 Difference settings dialog box

Difference is a command that calculates the temperature difference between two measurement markers, or the reference temperature and a measurement marker.

Figure 8.47 Explanations of the **Difference settings** dialog box

Label	Value	Comments
Function	Configuration-dependent	Move the joystick left/right to select the first function in the difference calculation.
Identity	**1–10**	Select a number between **1** and **10** to assign an identity to this function.
Result	Depending on the **Function** settings	Move the joystick left/right to define the type of result the difference calculation will use for its calculations.
Function	Configuration-dependent	Move the joystick left/right to select the second function in the difference calculation.
Identity	**1–10**	Select a number between **1** and **10** to assign an identity to this function.
Result	Depending on the **Function** settings	Move the joystick left/right to define the type of result the difference calculation will use for its calculations.

8.2.5.3 Save

10393403;2

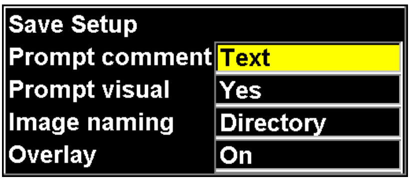


Figure 8.48 **Save Setup** dialog box

Figure 8.49 Explanations of the **Save Setup** dialog box

Label	Value	Comments
Prompt comment	▪ **None** ▪ **Text** ▪ **Voice**	▪ If **Text** is selected, the text comment dialog box will appear when you save an image. This function gives you a chance to add a text comment to the image. ▪ If **Voice** is selected, the voice comment dialog box will appear when you save an image. This function gives you a chance to add a voice comment to the image.
Prompt visual	▪ **Yes** ▪ **No**	If **Yes** is selected, the camera will change to *visual* mode when you save an image. This function gives you a chance to add a visual image to the infrared image.
Image naming	▪ **Unique counter** ▪ **Date** ▪ **Directory**	**SEE:** For a detailed explanation, see below.
Overlay	▪ **On** ▪ **Off**	▪ If **On** is selected, all on-screen graphics will be saved together with the image ▪ If **Off** is selected, only the image (together with any temperature information) will be saved **NOTE:** The difference between images saved with or without on-screen graphics will only be evident when looking at the images using a third-party image viewer.

Figure 8.50 Naming based on unique counter – explanations

Typical syntax: IR_nnnn.jpg	
IR or DC or SEQ	▪ IR = infrared image ▪ DC = visual image ▪ SEQ = sequence image
nnnn	Unique counter

Example	IR_0003.jpg
Comment	The counter will be reset when exceeding 9999, or when you point to **Factory default** on the **Setup** menu and press the joystick.

Figure 8.51 Naming based on current date – explanations

Typical syntax: IR_YYMMDD_nnn.jpg	
IR or DC or SEQ	▪ IR = infrared image ▪ DC = visual image ▪ SEQ = sequence image
YYMMDD	Current date. The format depends on your settings in the **Local settings** dialog box.
nnn	Counter within directory
Example	IR_020909_001.jpg
Comment	The counter will be reset every day.

Figure 8.52 Naming based on current directory – explanations

Typical syntax: IR_DIRE_nnn.jpg	
IR or DC or SEQ	▪ IR = infrared image ▪ DC = visual image ▪ SEQ = sequence image
DIRE	The first four letters in the directory name
nnn	Counter within directory
Example	IR_ COMP_003.jpg

8.2.5.4 Alarm

10439703;1

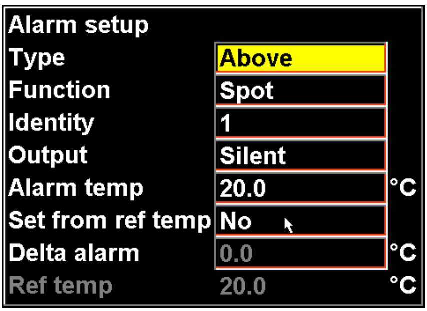


Figure 8.53 **Alarm Setup** dialog box

Figure 8.54 Explanations of the **Alarm setup** dialog box

Label	Value	Explanation
Type	■ **Off** ■ **Above** ■ **Below**	■ Select **Off** to disable the alarm. ■ Select **Above** to assign an alarm color to all pixels above the alarm temperature. ■ Select **Below** to assign an alarm color to all pixels below the alarm temperature.
Function	Configuration-dependent	Select any one of the measurement functions to define which function's temperature value should trigger the alarm.
Identity	Configuration-dependent	Select a number to assign an identity to the function above.
Output	■ **Silent** ■ **Beep**	■ Select **Silent** to make the background of the corresponding measurement function turn red when an alarm is triggered ■ Select **Beep** to additionally make the camera trigger a beep when an alarm is triggered.
Alarm temp	User-defined	Enter a temperature value by pressing the navigation pad left/right.
Set from ref temp	■ **Yes** ■ **No**	Select **Yes** or **No** to define whether the alarm temperature should be set from the reference temperature of the camera or not.
Delta alarm	N/A	Enter an delta alarm value by pressing the navigation pad left/right.
Ref temp	User-defined	For information purposes only. The reference temperature is calculated and updated 'on the fly'.

8.2.5.5 *Digital video*

NOTE: Depending on your camera configuration, this feature may – in whole or in part – be an extra option.

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Figure 8.55 Digital video dialog box

Figure 8.56 Explanations of the **Digital video** dialog box

Label	Value	Comments
Mode	■ **DCAM** ■ **DV**	**NOTE:** Disconnect the FireWire cable from the camera before carrying out this procedure. Move the joystick left/right to select digital video mode (**DV** or **DCAM**).
Link	■ **Active** ■ **Idle**	**NOTE:** Link status settings should only be changed when **DV** mode is selected above. ■ When establishing a connection between the camera and a passive digital video unit – such as a DV recorder – the image transmission needs to be activated from the camera. To do this, move the joystick left/right to select **Active**. ■ When establishing a connection between the camera and an active digital video unit – such as a PC – the unit itself will activate and deactivate the image transmission.

8.2.5.6 Power

10392703;2

Figure 8.57 Power Setup dialog box

Figure 8.58 Explanations of the **Power Setup** dialog box

Label	Value	Comments
Auto power off	▪ **None** ▪ **10 min**	Move the joystick left/right to specify the time after which the camera will be switched off if it is not used.
Display power off	▪ **None** ▪ **30 sec** ▪ **60 sec**	Move the joystick left/right to specify the time after which the display will be switched off if it is not used.
LCD illumination	▪ **Low** ▪ **Medium** ▪ **High**	Move the joystick left/right to specify the level of background illumination of the LCD.

NOTE: For protective reasons, the LCD will be switched off if the detector temperature exceeds +60 °C (+149 °F) and the camera will be switched off if the detector temperature exceeds +68 °C (+154.4 °F)

8.2.5.7 Status bar

10392803;2

Figure 8.59 Status bar dialog box

Figure 8.60 Explanations of the **Status bar** dialog box

Label	Value	Comments
Date/time	▪ **On** ▪ **Off**	Move the joystick left/right to enable/disable this label on the status bar.
Distance	▪ **On** ▪ **Off**	Move the joystick left/right to enable/disable this label on the status bar.
Emissivity	▪ **On** ▪ **Off**	Move the joystick left/right to enable/disable this label on the status bar.
T Reflected	▪ **On** ▪ **Off**	Move the joystick left/right to enable/disable this label on the status bar.
T Atmosphere	▪ **On** ▪ **Off**	Move the joystick left/right to enable/disable this label on the status bar.
Relative humidity	▪ **On** ▪ **Off**	Move the joystick left/right to enable/disable this label on the status bar.
Range	▪ **On** ▪ **Off**	Move the joystick left/right to enable/disable this label on the status bar.
Lens	▪ **On** ▪ **Off**	Move the joystick left/right to enable/disable this label on the status bar.
Zoom	▪ **On** ▪ **Off**	Move the joystick left/right to enable/disable this label on the status bar.
Text comment	▪ **On** ▪ **Off**	Move the joystick left/right to enable/disable this label on the status bar.

8.2.5.8 Buttons

10393103;2

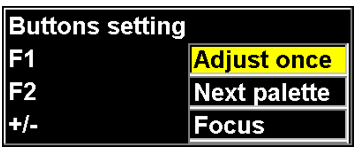

Figure 8.61 **Buttons Settings** dialog box

Figure 8.62 Explanations of the **Buttons Setting** dialog box

Label	Value	Comments
F1	■ **None** ■ **Adjust once** ■ **Auto focus** ■ **Reverse palette** ■ **Next palette** ■ **Visual/IR** ■ **Update ref temp**	Move the joystick left/right to specify the function of the **F1** button on the left side of the camera.
F2	■ **None** ■ **Adjust once** ■ **Auto focus** ■ **Reverse palette** ■ **Next palette** ■ **Visual/IR** ■ **Update ref temp**	Move the joystick left/right to specify the function of the **F2** button on the left side of the camera.
+/-	■ **None** ■ **Level** ■ **Span** ■ **Focus**	Move the joystick left/right to specify the function of the +/- button on the left side of the camera.

SEE ALSO: For more information about buttons and their functions, see section 7.2 – Keypad buttons & functions on page 33.

8.2.5.9 Date/time

10393803;2

Figure 8.63 **Date/Time** dialog box

Figure 8.64 Explanations of the **Date/Time** dialog box

Label	Value
Year	1970–2036
Month	1–12
Day	1 –31

Label	Value
Hour	▪ **12 a.m.–12 p.m.** ▪ **1–24** The format depends on the settings in the **Local settings** dialog box.
Minute	00–59
Second	00–59

8.2.5.10 Local settings

10393903;2

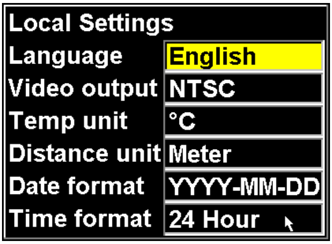

Figure 8.65 Local settings dialog box

Figure 8.66 Explanations of the **Local settings** dialog box

Label	Value
Language	Configuration-dependent **NOTE:** The camera program will be restarted when you change the language. This will take a few seconds.
Video output	▪ **NTSC** ▪ **PAL**
Temp unit	▪ **°C** ▪ **°F**
Distance unit	▪ **Feet** ▪ **Meters**
Date format	▪ **YYYY-MM-DD** ▪ **YY-MM-DD** ▪ **MM/DD/YY** ▪ **DD/MM/YY**
Time format	▪ **24 hour** ▪ **AM/PM**

8.2.5.11 Camera info

The **Camera info** dialog box shows information about memory usage, battery status, serial numbers, software revision *etc.* No changes can be made.

8.2.5.12 Profile

Point to **Profile** and click **Save...** to save all current user settings as a user profile. Once you have saved a profile you can load it again by pointing to **Load...**.

Examples of user settings that are saved in the profile:

- Measurement markers
- Object parameters
- Range
- Level & span
- Palette
- Image settings
- Power settings
- Date & time

8.2.5.13 Factory default

Point to **Factory default** and press the joystick to reset the camera to the factory settings.

NOTE: The camera will be restarted when you restore factory settings. This will take a few seconds.

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9 Electrical power system

The camera's electrical power system consists of the following parts:

- a removable battery
- a power supply
- an internal battery charger
- a stand-alone, external battery charger

The camera may powered either by using the battery, or by using the power supply. When using the power supply, the battery will – if it's inserted in the battery compartment – automatically be charged. You can still use the camera during charging.

NOTE: Please note the following:

- The camera is shipped with charged batteries. To increase the battery life, the battery should be fully discharged and charged a couple of times. You can do this by using the camera until the battery is fully depleted.
- The same power supply can be used for both the internal battery charger and the external battery charger.
- The operation time of the camera when run on a battery is substantially shorter in low temperatures.

The removable battery gives an operation time of approx. 1.5–2 hours. When **Battery low** is displayed on the screen it is time to charge the battery.

9.1 Internal battery charging

To charge the battery internally, follow the instructions below.

Step	Action
1	Make sure that the battery is correctly inserted into the camera.
2	Connect the power supply cable to the camera.
3	The message **Charging battery** will appear on the screen.
4	While charging, the battery status symbol will pulse until the battery is fully charged.

9.2 External battery charging

10345803;3

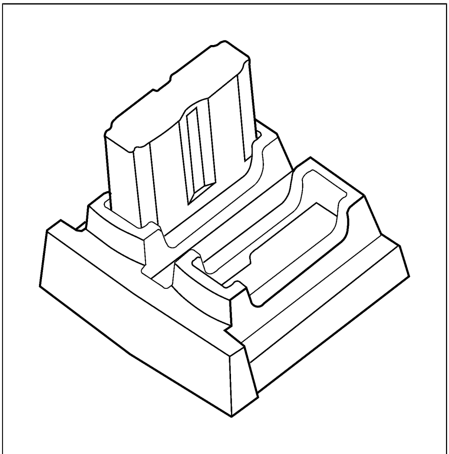

Figure 9.1 Stand-alone battery charger

The battery status while charging is indicated by a number of LEDs. See the figure below.

10346203;4

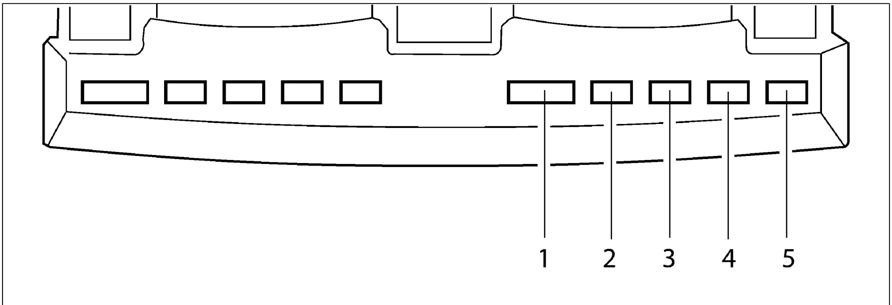

Figure 9.2 LED indicators on the stand-alone battery charger.

Figure 9.3 LED indicators – explanations

Situation	Indicator #	Color & mode
The charger is under power, but no battery is inserted	1	Fixed red light
The charger is under power, and a battery is inserted	1	Fixed green light
The battery is too cold or too warm	1	Flashing green light

Situation	Indicator #	Color & mode
The battery is out of order	1	Flashing red light
The battery is now being charged	5 to 2	Pulsing green light from LED 5 to LED 2 Each LED represents 25 % battery capacity and will be switched on accordingly.

9.3 Battery safety warnings

- Do not place the battery in fire or heat the battery.
- Do not install the battery backwards so that the polarity is reversed.
- Do not connect the positive terminal and the negative terminal of the battery to each other with any metal object (such as wire).
- Do not pierce the battery with nails, strike the battery with a hammer, step on the battery, or otherwise subject it to strong impacts or shocks.
- Do not solder directly onto the battery.
- Do not expose the battery to water or salt water, or allow the battery to get wet.
- Do not disassemble or modify the battery. The battery contains safety and protection devices which, if damaged, may cause the battery to generate heat, explode or ignite.
- Do not place the battery on or near fires, stoves, or other high-temperature locations.
- When the battery is worn out, insulate the terminals with adhesive tape or similar materials before disposal.
- Immediately discontinue use of the battery if, while using, charging, or storing the battery, the battery emits an unusual smell, feels hot, changes color, changes shape, or appears abnormal in any other way. Contact your sales location if any of these problems are observed.
- In the event that the battery leaks and the fluid gets into one's eye, do not rub the eye. Rinse well with water and immediately seek medical care. If left untreated the battery fluid could cause damage to the eye.
- When charging the battery, only use a specified battery charger.
- Do not attach the batteries to a power supply plug or directly to a car's cigarette lighter.
- Do not place the batteries in or near fire, or into direct sunlight. When the battery becomes hot, the built-in safety equipment is activated, preventing the battery from charging further, and heating the battery can destroy the safety equipment and can cause additional heating, breaking, or ignition of the battery.
- Do not continue charging the battery if it does not recharge within the specified charging time. Doing so may cause the battery to become hot, explode, or ignite.

- The temperature range over which the battery can be charged is 0–+45 °C (+32–+113 °F). Charging the battery at temperatures outside of this range may cause the battery to become hot or to break. Charging the battery outside of this temperature range may also harm the performance of the battery or reduce the battery's life expectancy.
- Do not discharge the battery using any device except for the specified device. When the battery is used in devices aside from the specified device it may damage the performance of the battery or reduce its life expectancy, and if the device causes an abnormal current to flow, it may cause the battery to become hot, explode, or ignite and cause serious injury.
- The temperature range over which the battery can be discharged is -15–+45 °C (+18.8–+113 °F). Use of the battery outside of this temperature range may damage the performance of the battery or may reduce its life expectancy.

10 A note on LEMO connectors

10.1 How to connect & disconnect LEMO connectors

The male LEMO connectors used on the camera cables are designed to lock securely to the female connectors on the camera body. A connector consists of a fixed inner tube and a sliding outer tube. The outer tube controls the locking teeth. To unlock the connector, pull the outer tube in the indicated direction. See the figure below

NOTE: Never pull the cable.

10062403;2

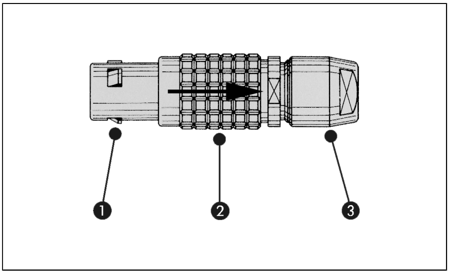

Figure 10.1 Straight body LEMO connector.

Callout	Description
1	Locking teeth
2	Sliding outer tube
3	Fixed inner tube

10403003;1

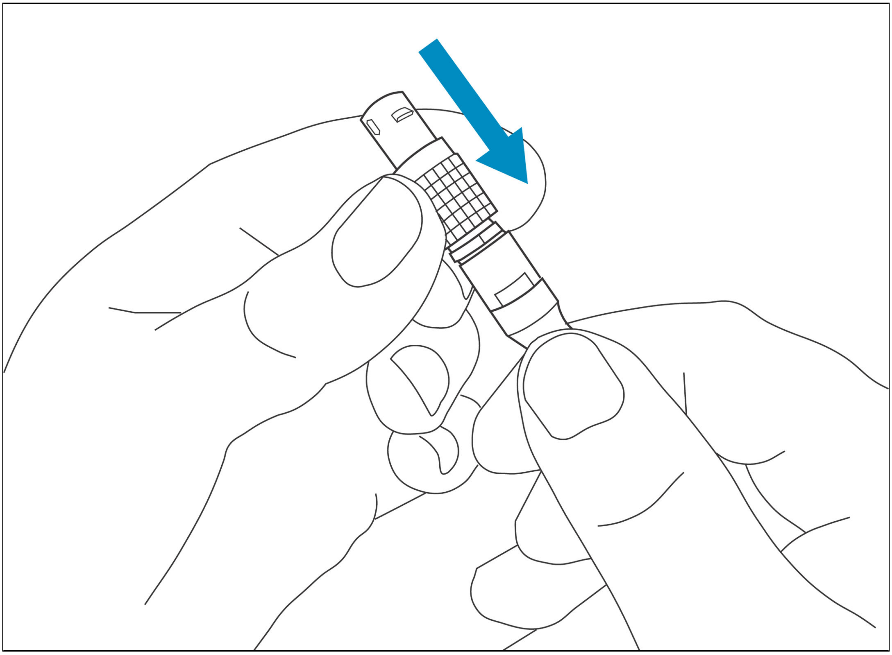

Figure 10.2 Unlocking a LEMO connector

11 Maintenance & cleaning

11.1 Camera body, cables & accessories

The camera body, cables and accessories may be cleaned by wiping with a soft cloth. To remove stains, wipe with a soft cloth moistened with a mild detergent solution and wrung dry, then wipe with a dry soft cloth.

➲ Do not use benzene, thinner, or any other chemical product on the camera, the cables or the accessories, as this may cause deterioration.

11.2 Lenses

All lenses are coated with an anti-reflective coating and care must be taken when cleaning them. Cotton wool soaked in 96 % ethyl alcohol (C_2H_5OH) may be used to clean the lenses. The lenses should be wiped once with the solution, then the cotton wool should be discarded.

If ethyl alcohol is unavailable, DEE (*i.e.* 'ether' = diethylether, $C_4H_{10}O$) may be used for cleaning.

Sometimes drying marks may appear on the lenses. To prevent this, a cleaning solution of 50 % acetone (*i.e.* dimethylketone, $(CH_3)_2CO$)) and 50 % ethyl alcohol (C_2H_5OH) may be used.

➲ Please note the following:

- Excessive cleaning of the lenses may wear down the coating.
- The chemical substances described in this section may be dangerous. Carefully read all warning labels on containers before using the substances, as well as applicable MSDS (Material Safety Data Sheets).

12 Troubleshooting

Problem	Possible reason	Solution
The LCD on the remote control, or the viewfinder, displays no image at all.	The camera may have been switched off automatically due the settings in the **Power setup** dialog box.	Press ON/OFF to switch on the camera.
	The LCD may have been switched off automatically due to the settings in the **Power setup** dialog box.	Press ON/OFF to switch on the camera.
	The connector on the remote control cable may not be properly inserted into the remote control connector camera.	Verify that the connector on the remote control cable is properly inserted.
	There is no battery in the battery compartment.	Insert a fully charged battery.
	There is a battery in the battery compartment, but the battery is depleted.	Charge the battery.
	If you are using the power supply, the power supply connector may not be properly inserted into the power connector on the camera.	Verify that the power supply connector is properly inserted.
	If you are using the power supply, the mains plug may not be properly plugged in into a mains supply.	Verify that the mains plug is properly plugged in.
	If you are using the power supply, the mains cable may not be properly plugged in into the power supply.	Verify that the mains cable is properly plugged in.
The LCD/viewfinder displays an image, but it is of poor quality.	The level needs to be changed.	Change the level.
	The span needs to be changed	Change the span.
	The camera needs to be autoadjusted.	Autoadjust the camera.
	The target may be hotter or colder than the temperature range you are currently using.	Change the range.
	A different palette may be more suitable for imaging the target than the one you are currently using.	Change the palette.

Problem	Possible reason	Solution
The LCD/viewfinder displays an infrared image, but it is blurry.	The target may be out of focus.	Focus the camera by pressing and holding down the A button for a few seconds.
	The ocular diopter adjustment of the viewfinder may be incorrect.	Change the ocular diopter adjustment by rotating the adjustment knob on the bottom side of the viewfinder.
The LCD/viewfinder displays a visual image, but it is blurry.	The target may be out of focus.	Focus the visual camera by rotating the focus ring on the visual camera.
The LCD/viewfinder displays an image, but it is of low illumination.	The illumination of the LCD may have accidentally been set to too low a value.	Change the illumination of the LCD.
When connecting the infrared camera to an external video monitor, no image appears.	The video cable connector may not be properly inserted into the video connector on the camera.	Verify that the video cable connector is properly inserted.
	The video cable connector may not be properly inserted into the video connector on the external monitor.	Verify that the video cable connector is properly inserted.
	The camera may have accidentally been set to PAL video format, while the external video monitor will only display NTSC video format, and vice versa.	Change the video format.
It is not possible to store any more images in the camera.	The internal flash memory may be full.	To be able to save more images, download the images to your computer using ThermaCAM QuickView.
	The CompactFlash card may be full.	To be able to save more images, move the images from the CompactFlash card by downloading them to your computer using ThermaCAM QuickView, or replace the card with an empty card.
The LCD/viewfinder does not display the correct date & time.	The camera may have accidentally been set to the wrong date & time.	Change the date & time.

13 Technical specifications & dimensional drawings

NOTE: FLIR Systems reserves the right to discontinue models, parts and accessories, and other items, or change specifications at any time without prior notice.

13.1 Imaging performance

Field of view/min. focus distance	24° × 18°/0.3 m (0.98 ft)
Spatial resolution	1.3 mrad
Image frequency	50/60 Hz, non-interlaced
Electronic zoom function	2x, 4x, 8x – interpolating
Focus	Automatic or manual
Digital image enhancement	Adaptive digital noise reduction
Built-in digital video	640 × 480 pixels, full color

13.2 Detector

Type	Focal Plane Array (FPA), uncooled microbolometer, 320 × 240 pixels
Spectral range	7.5–13 μm

13.3 Image presentation

Viewfinder	Built-in, high resolution color LCD (TFT)
LCD on remote control	4"

13.4 Temperature ranges

Temperature range, standard	-40–+120 °C (-40–+248 °F) -10–+55 °C (+14–+131 °F) ±0–+500 °C (+32–+932 °F) – **NOTE:** Depending on your camera configuration, one or several of these ranges may be disabled.
Temperature range, extra options	+350–+1500 °C (+662–+2732 °F) +350–+2000 °C (+662–+3632 °F) – –
Accuracy	± 2 °C/± 3.6 °F or ± 2 % of reading
Emissivity correction	Set by number, or by selection in predefined list
Atmospheric transmission correction	Automatic, based on input from distance, atmospheric temperature, and relative humidity.
Optics transmission correction	Automatic, based on signals from internal sensors
Reflected ambient temperature correction	Yes
External optics correction	Yes

13.5 Laser LocatIR

Classification	Class 2
Type	Semiconductor AlGaInP diode laser, 1 mW / 635 nm (red)

13.6 Electrical power system

Battery type	Rechargeable Li/Ion battery
Battery operating time	1.5–2 hours. Display shows battery status
Battery charging	In camera (AC adapter) or stand-alone 2-bay charger
AC operation	AC adapter, 90–260 VAC, 50/60 Hz, 12 VDC out
Voltage	9–16 VDC (11–16 VDC when charging)

Power management	User-selectable: ▪ automatic shut-down ▪ stand-by ▪ sleep and ▪ deep-sleep mode

13.7 Environmental specifications

Operating temperature range	-15–+50 °C (+5–+122 °F)
Storage temperature range	-40–+70 °C (-40–+158 °F)
Humidity	Operating & storage:10–95 %, non-condensing,
Encapsulation	IP 54 (IEC 529)
Shock	25 g, IEC 68-2-29
Vibration	2 g, IEC 68-2-6

13.8 Physical specifications

Weight	2.0 kg (4.41 lb) incl. battery & remote control
Size (L × W × H)	234 × 124 × 161 mm (9.21 × 4.88 × 6.34")
Tripod mounting	Standard, 1/4"-20

13.9 Interfaces & connectors

Computer interfaces	USB Rev 2.0 (full speed) RS-232 (extra option) FireWire (IEEE 1394a, 100/200/400 Mbps)
Audio input/output	Headset connection for voice annotation of images
Interface for integrated LCD & remote control	Yes
Power input	9–16 VDC (11–16 VDC when charging), standard 2.5 mm DC connector. Polarity protected
CVBS	Standard RCA connector for composite video CVBS (ITU-R BT.470 PAL/SMPTE 170M NTSC)
IrDA	Infrared communications link (IrDA 1.4 SIR, Baud rate 115 kBaud)

13.10 Pin configurations

13.10.1 Headset connector

10402603;1

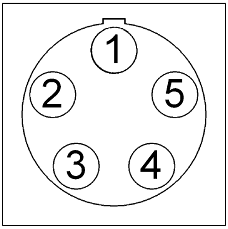

Figure 13.1 Pin configuration for headset connector (on camera – operator's side)

Connector type:	**LEMO 05B, 5 pins**	
Signal name	**Type**	**Pin number**
SPEAK_R	OUT	1
GNDD	GND	2
MIC_POS	IN	3
GNDD	GND	4
SPEAK_L	OUT	5

10563003;1

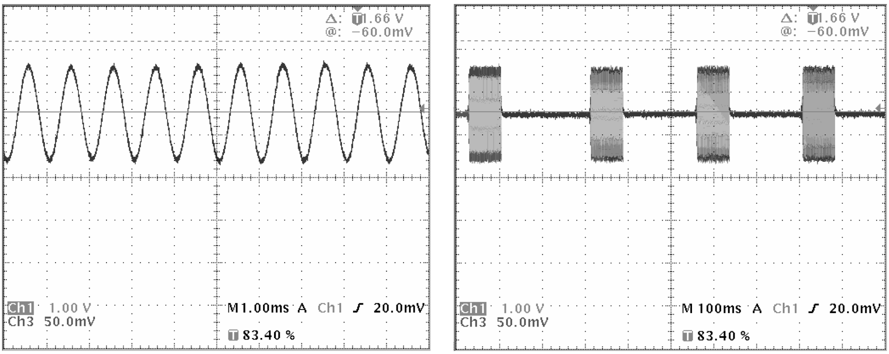

Figure 13.2 Graphical representation of alarm output signal. The alarm output signal is a 1 kHz signal with an amplitude of 2 Vpp (load 1kΩ). The signal can drive loads as low as 16 Ω. The signal is available in pin 1 of the headset connector.

13.10.2 RS-232/USB connector

10402703;1

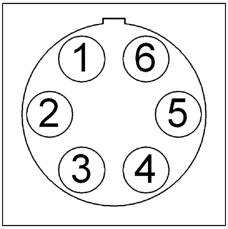

Figure 13.3 Pin configuration for RS-232/USB connector (on camera – operator's side)

Connector type:	LEMO 1B, 6 pins	
Signal name	**Type**	**Pin number**
USB_D+	I/O	1
USB_D-	I/O	2
USB_POWER	OUT	3
GND	GND	4
RS232_TX1	OUT	5
RS232_RX1	IN	6

10563403;1

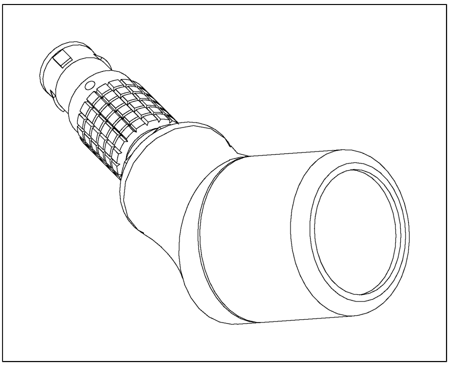

Figure 13.4 Video lamp, to be inserted in the RS-232/USB connector

- Power: 0.7 W
- Voltage: 5 V ± 10%
- Luminous intensity: 35 000 mcd in the middle of the light beam; 20 000 mcd measured at an angle of ±10° from the light beam, and 5 000 mcd measured at an angle of ±20° from the light beam.

Connector type:	**LEMO 1B, 6 pins. The video lamp uses the same connector as the RS-232/USB signal (see figure 13.3 on page 93).**	
Signal name	**Type**	**Pin number**
POWER	OUT	3
GND	GND	4

13.10.3 Remote control connector

10402803;1

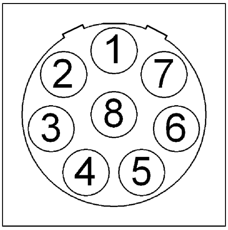

Figure 13.5 Pin configuration for remote control connector (on camera – operator's side)

Connector type:	**LEMO 1B, 8 pins**	
Signal name	**Type**	**Pin number**
P8VA	POWER	1
SCL_D	I/O	2
GNDD	GND	3
LVDS_DISP-	OUT	4
LVDS_DISP+	OUT	5
GNDD	GND	6
SDA_D	I/O	7
P8VA	POWER	8

13.10.4 Power connector

10402503;1

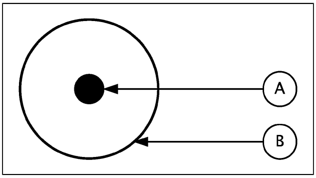

Figure 13.6 Pin configuration for power connector (on camera – operator's side). **A:** Center pin; **B:** Chassis

Connector type:	**2.5 mm DC**	
Signal name	**Type**	**Pin number**
+12V	POWER	CENTER PIN
GND	POWER	CHASSIS

13.10.5 CVBS connector

10402503;1

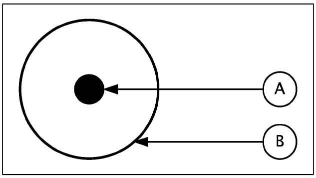

Figure 13.7 Pin configuration for CVBS connector (on camera – operator's side). **A:** Center pin; **B:** Chassis

Connector type:	**RCA/PHONO**	
Signal name	**Type**	**Pin number**
CVBS	VIDEO	CENTER PIN
GND	POWER	CHASSIS

13.10.6 FireWire connector

10402303;1

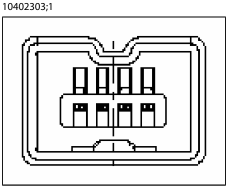

Figure 13.8 Pin configuration for FireWire connector (on camera – operator's side)

Connector type:	FireWire, 4 pins	
Signal name	**Type**	**Pin number**
TPB0-	OUT	1
TPB0+	OUT	2
TPA0-	IN	3
TPA1+	IN	4

13.11 Relationship between fields of view and distance

10401803;1

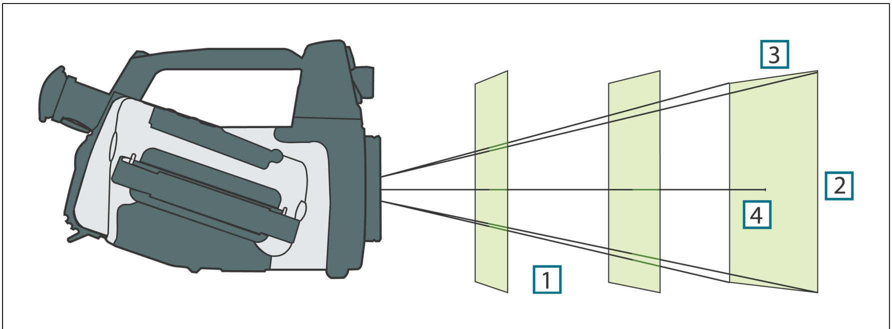

Figure 13.9 Relationship between fields of view and distance. **1:** Distance to target; **2:** VFOV = vertical field of view; **3:** HFOV = horizontal field of view, **4:** IFOV = instantaneous field of view (spot size).

Figure 13.10 Horizontal, vertical and instantaneous fields of view for certain distances to targets. **D** = distance to target.

	D →	**1.20**	**5.00**	**10.00**	**25.00**	**50.00**	**100.00**	**m**
	D →	**3.90**	**16.40**	**32.80**	**82.00**	**164.00**	**327.90**	**ft.**
7°	HFOV		0.61	1.22	3.06	6.12	12.23	m
7°	HFOV		2.01	4.01	10.03	20.05	40.11	ft.
7°	VFOV		0.46	0.92	2.29	4.59	9.17	m
7°	VFOV		1.50	3.01	7.52	15.04	30.08	ft.
7°	IFOV		1.91	3.82	9.56	19.11	38.23	mm
7°	IFOV		0.08	0.15	0.38	0.75	1.50	in.
12°	HFOV	0.25	1.05	2.10	5.26	10.51	21.02	m
12°	HFOV	0.83	3.45	6.89	17.23	34.46	68.92	ft.

	D →	**1.20**	**5.00**	**10.00**	**25.00**	**50.00**	**100.00**	**m**
	D →	**3.90**	**16.40**	**32.80**	**82.00**	**164.00**	**327.90**	**ft.**
12°	VFOV	0.19	0.79	1.58	3.94	7.88	15.77	m
12°	VFOV	0.62	2.58	5.17	12.92	25.85	51.69	ft.
12°	IFOV	0.79	3.28	6.57	16.42	32.85	65.69	mm
12°	IFOV	0.03	0.13	0.26	0.65	1.29	2.59	in.
24°	HFOV	0.51	2.13	4.25	10.63	21.26	42.51	m
24°	HFOV	1.67	6.97	13.94	34.85	69.69	139.38	ft.
24°	VFOV	0.38	1.59	3.19	7.97	15.94	31.88	m.
24°	VFOV	1.25	5.23	10.45	26.13	52.27	104.54	ft.
24°	IFOV	1.59	6.64	13.28	33.21	66.42	132.85	mm
24°	IFOV	0.06	0.26	0.52	1.31	2.62	5.23	in.
45°	HFOV	0.99	4.14	8.28	20.71	41.42	82.84	m
45°	HFOV	3.26	13.58	27.16	67.90	135.81	271.62	ft.
45°	VFOV	0.75	3.11	6.21	15.53	31.07	62.13	m
45°	VFOV	2.44	10.19	20.37	50.93	101.86	203.71	ft.
45°	IFOV	3.11	12.94	25.89	64.72	129.44	258.88	mm
45°	IFOV	0.12	0.51	1.02	2.55	5.10	10.19	in.
65°	HFOV	1.53	6.37	12.74	31.85	63.71	127.41	m
65°	HFOV	5.01	20.89	41.78	104.44	208.88	417.75	ft.
65°	VFOV	1.15	4.78	9.56	23.89	47.78	95.56	m
65°	VFOV	3.76	15.67	31.33	78.33	156.66	313.31	ft.
65°	IFOV	4.78	19.91	39.82	99.54	199.08	398.17	mm
65°	IFOV	0.19	0.78	1.57	3.92	7.84	15.68	in.
80°	HFOV	2.01	8.39	16.78	41.95	83.91	167.82	m
80°	HFOV	6.60	27.51	55.02	137.56	275.11	550.23	ft.
80°	VFOV	1.51	6.29	12.59	31.47	62.93	125.86	m

	D →	**1.20**	**5.00**	**10.00**	**25.00**	**50.00**	**100.00**	**m**
	D →	**3.90**	**16.40**	**32.80**	**82.00**	**164.00**	**327.90**	**ft.**
80°	VFOV	4.95	20.63	41.27	103.17	206.34	412.67	ft.
80°	IFOV	6.29	26.22	52.44	131.11	262.22	524.44	mm
80°	IFOV	0.25	1.03	2.06	5.16	10.31	20.65	in.

Figure 13.11 F-number and close focus limits for various lenses

Lens →	**7°**	**12°**	**24°**	**45°**	**65°**	**80°**
Close focus limit (m)	4	1.2	0.3	0.1	0.2	0.15
Close focus limit (ft.)	13.11	3.93	0.98	0.32	0.64	0.49
f-number	1.0	1.0	1.0	1.0	1.5	1.0

13.12 Basic dimensions – battery charger

10388003;3

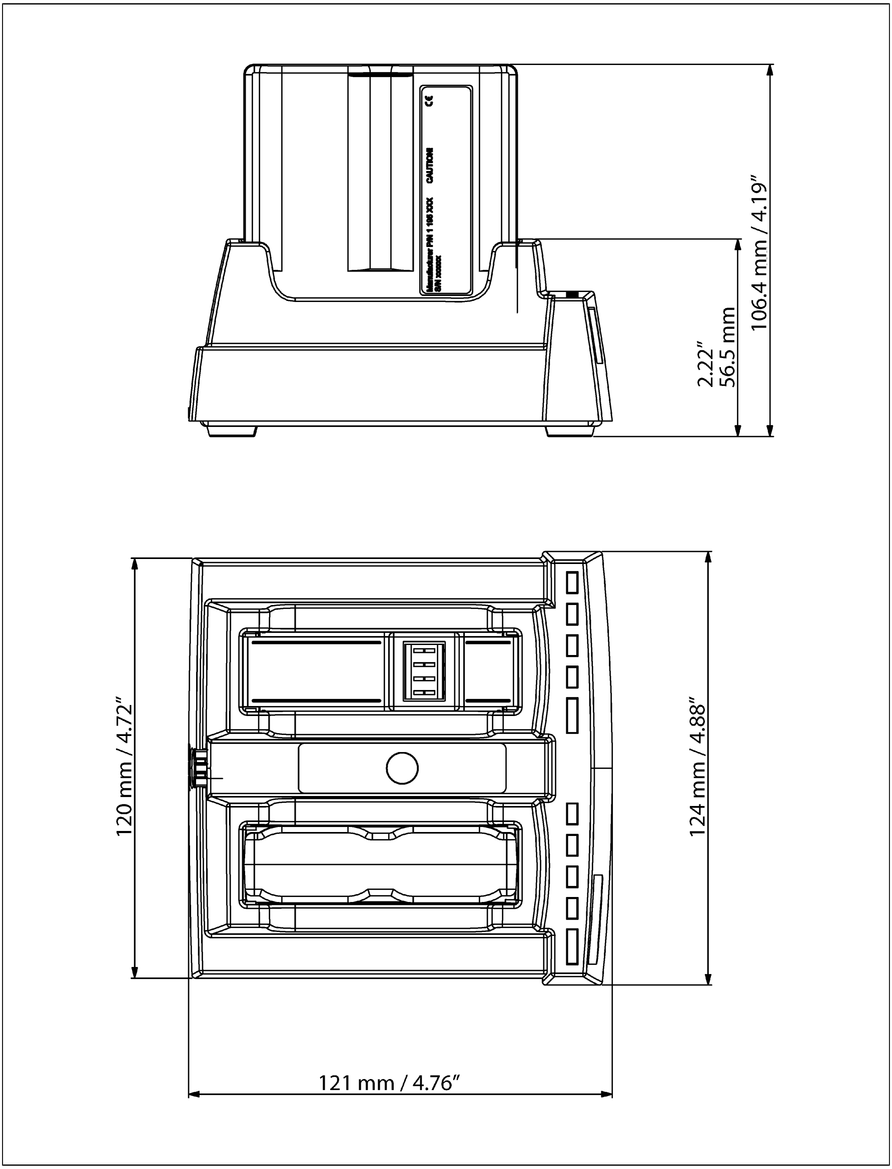

Figure 13.12 Overall dimensions of the battery charger

13.13 Basic dimensions – battery

10388103;3

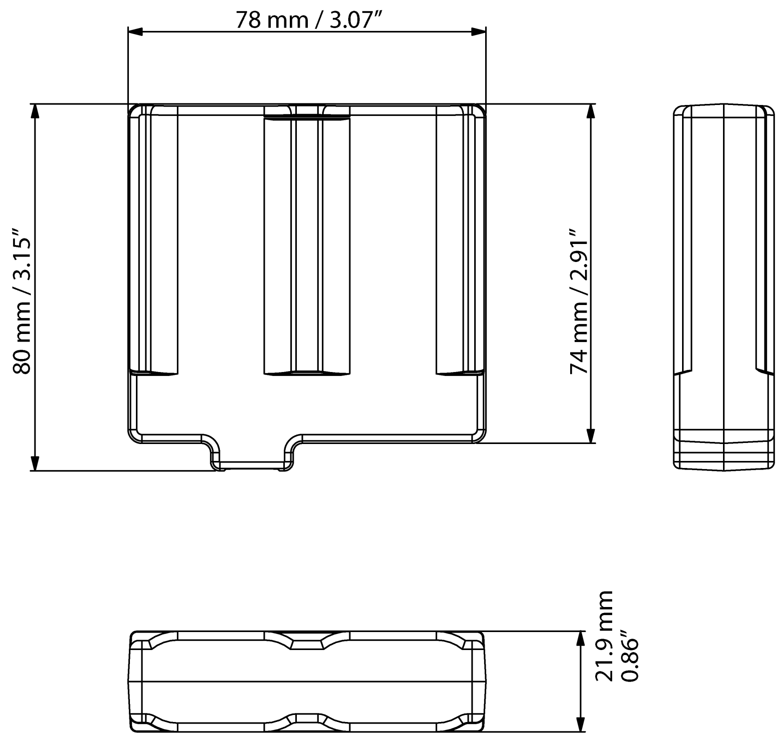

Figure 13.13 Overall dimensions of the battery

13.14 Basic dimensions – remote control

10394003;3

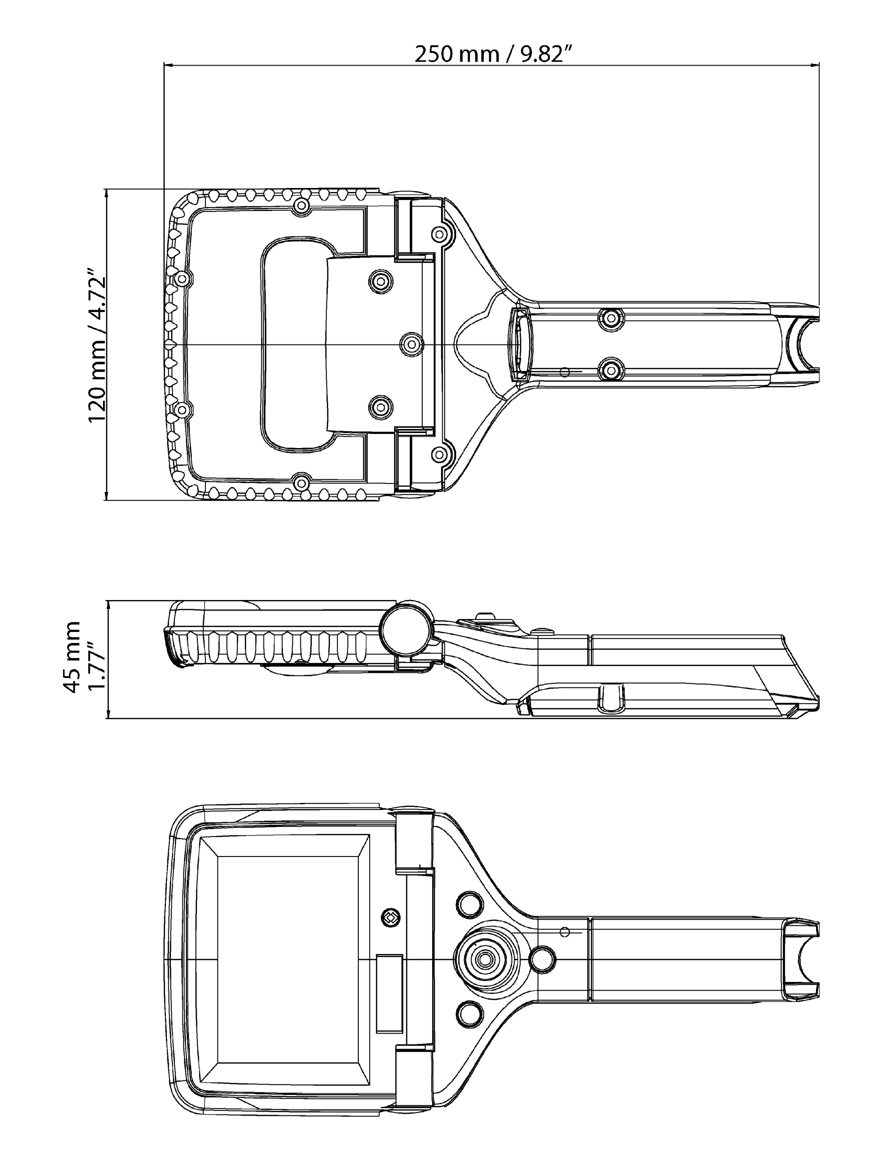

Figure 13.14 Overall dimensions of the remote control

13.15 Basic dimensions – camera

10346503;3

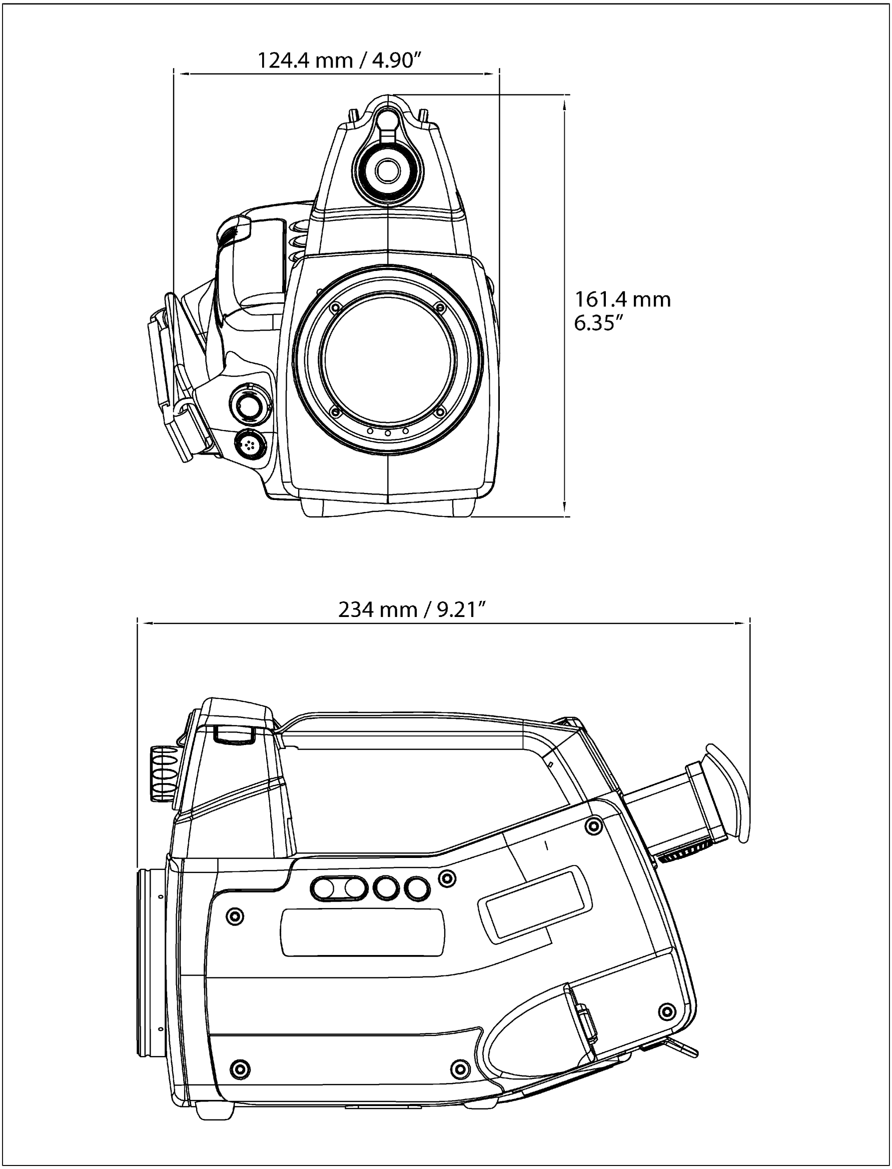

Figure 13.15 Overall dimensions of the camera

13.16 Basic dimensions – camera

10563203;1

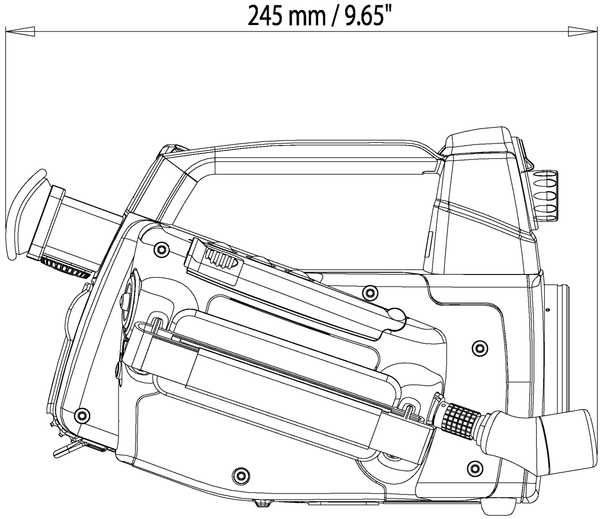

Figure 13.16 Overall dimensions of the camera, when the video lamp is mounted

13.17 Basic dimensions – video lamp

10563303;1

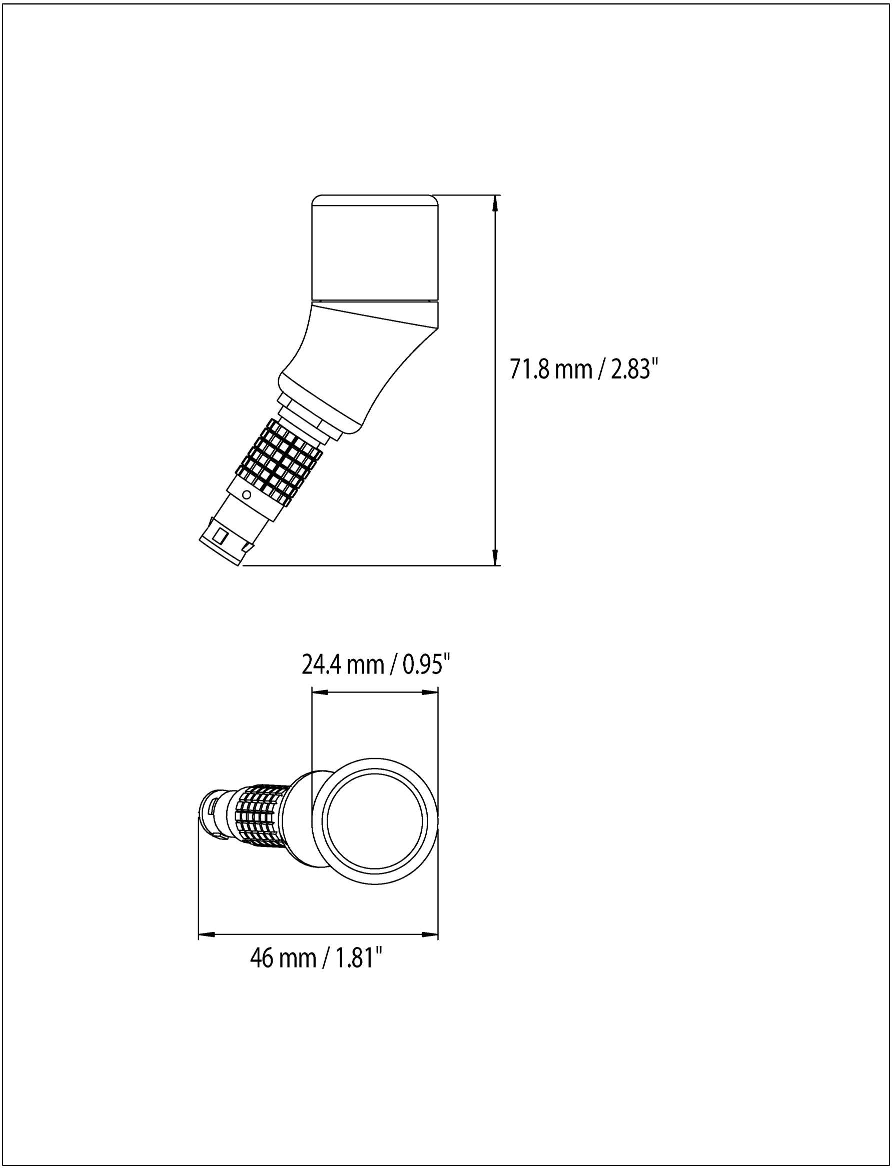

Figure 13.17 Overall dimensions of the video lamp

13.18 Basic dimensions – camera

10352203;3

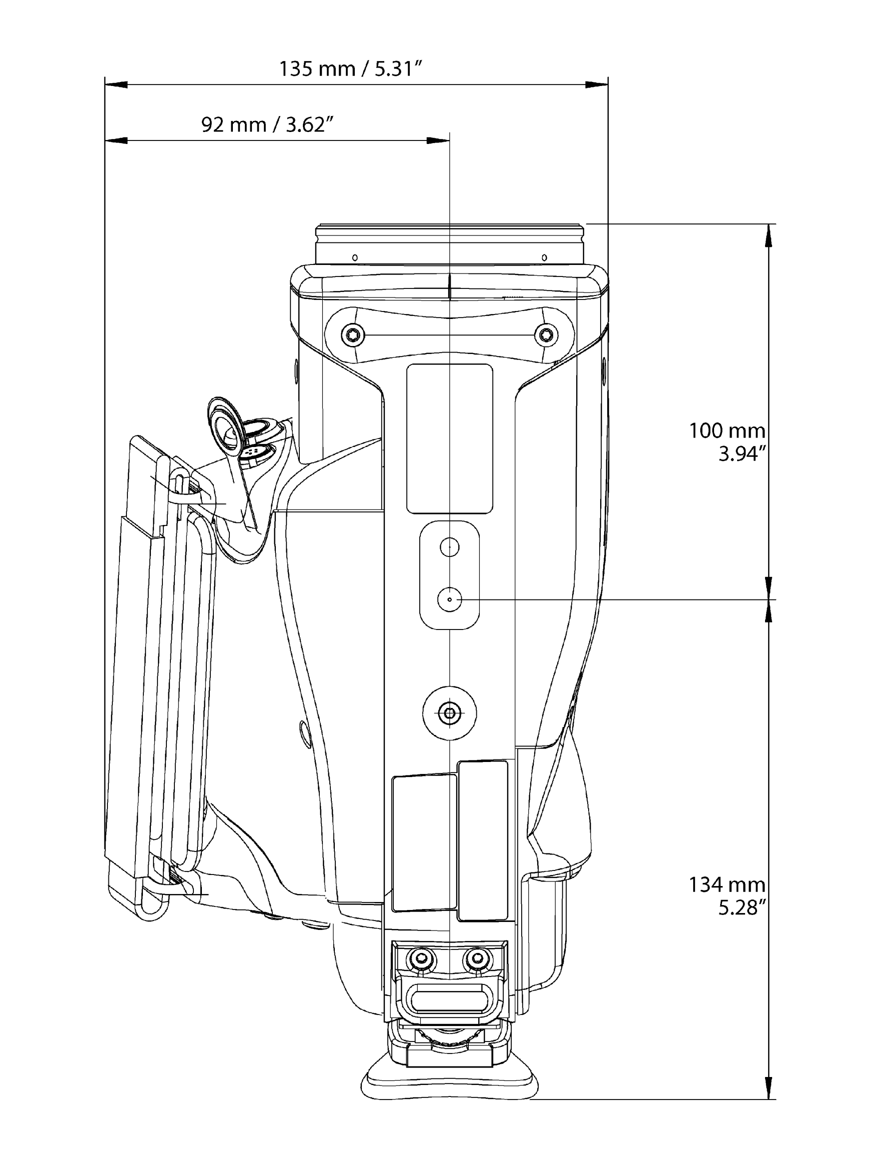

Figure 13.18 Location of the standard tripod mount (1/4"-20) on the bottom side of the camera

14 Glossary

Figure 14.1 Glossary of common infrared terms & expressions

Term or expression	Explanation
absorption (absorption factor)	The amount of radiation absorbed by an object relative to the received radiation. A number between 0 and 1.
ambient	Objects and gases that emit radiation towards the object being measured.
atmosphere	The gases between the object being measured and the camera, normally air.
autoadjust	A function making a camera perform an internal image correction.
autopalette	The IR image is shown with an uneven spread of colors, displaying cold objects as well as hot ones at the same time.
blackbody	Totally non-reflective object. All its radiation is due to its own temperature.
blackbody radiator	An IR radiating equipment with blackbody properties used to calibrate IR cameras.
calculated atmospheric transmission	A transmission value computed from the temperature, the relative humidity of air and the distance to the object.
cavity radiator	A bottle shaped radiator with an absorbing inside, viewed through the bottleneck.
color temperature	The temperature for which the color of a blackbody matches a specific color.
conduction	The process that makes heat spread into a material.
continuous adjust	A function that adjusts the image. The function works all the time, continuously adjusting brightness and contrast according to the image content.
convection	The process that makes hot air or liquid rise.
difference temperature	A value which is the result of a subtraction between two temperature values.
dual isotherm	An isotherm with two color bands, instead of one.
emissivity (emissivity factor)	The amount of radiation coming from an object, compared to that of a blackbody. A number between 0 and 1.

Term or expression	Explanation
emittance	Amount of energy emitted from an object per unit of time and area (W/m^2)
estimated atmospheric transmission	A transmission value, supplied by a user, replacing a calculated one
external optics	Extra lenses, filters, heat shields etc. that can be put between the camera and the object being measured.
filter	A material transparent only to some of the infrared wavelengths.
FOV	Field of view: The horizontal angle that can be viewed through an IR lens.
FPA	Focal plane array: A type of IR detector.
graybody	An object that emits a fixed fraction of the amount of energy of a blackbody for each wavelength.
IFOV	Instantaneous field of view: A measure of the geometrical resolution of an IR camera.
image correction (internal or external)	A way of compensating for sensitivity differences in various parts of live images and also of stabilizing the camera.
infrared	Non-visible radiation, having a wavelength from about 2–13 μm.
IR	infrared
isotherm	A function highlighting those parts of an image that fall above, below or between one or more temperature intervals.
isothermal cavity	A bottle-shaped radiator with a uniform temperature viewed through the bottleneck.
Laser LocatIR	An electrically powered light source on the camera that emits laser radiation in a thin, concentrated beam to point at certain parts of the object in front of the camera.
laser pointer	An electrically powered light source on the camera that emits laser radiation in a thin, concentrated beam to point at certain parts of the object in front of the camera.
level	The center value of the temperature scale, usually expressed as a signal value.
manual adjust	A way to adjust the image by manually changing certain parameters.

Term or expression	Explanation
NETD	Noise equivalent temperature difference. A measure of the image noise level of an IR camera.
noise	Undesired small disturbance in the infrared image
object parameters	A set of values describing the circumstances under which the measurement of an object was made, and the object itself (such as emissivity, ambient temperature, distance etc.)
object signal	A non-calibrated value related to the amount of radiation received by the camera from the object.
palette	The set of colors used to display an IR image.
pixel	Stands for *picture element*. One single spot in an image.
radiance	Amount of energy emitted from an object per unit of time, area and angle ($W/m^2/sr$)
radiant power	Amount of energy emitted from an object per unit of time (W)
radiation	The process by which electromagnetic energy, is emitted by an object or a gas.
radiator	A piece of IR radiating equipment.
range	The current overall temperature measurement limitation of an IR camera. Cameras can have several ranges. Expressed as two blackbody temperatures that limit the current calibration.
reference temperature	A temperature which the ordinary measured values can be compared with.
reflection	The amount of radiation reflected by an object relative to the received radiation. A number between 0 and 1.
relative humidity	Percentage of water in the air, relative to what is physically possible. Air temperature dependent.
saturation color	The areas that contain temperatures outside the present level/span settings are colored with the saturation colors. The saturation colors contain an ‘overflow’ color and an ‘underflow’ color. There is also a third red saturation color that marks everything saturated by the detector indicating that the range should probably be changed.

Term or expression	Explanation
span	The interval of the temperature scale, usually expressed as a signal value.
spectral (radiant) emittance	Amount of energy emitted from an object per unit of time, area and wavelength (W/m^2/μm)
temperature range	The current overall temperature measurement limitation of an IR camera. Cameras can have several ranges. Expressed as two blackbody temperatures that limit the current calibration.
temperature scale	The way in which an IR image currently is displayed. Expressed as two temperature values limiting the colors.
thermogram	infrared image
transmission (or transmittance) factor	Gases and materials can be more or less transparent. Transmission is the amount of IR radiation passing through them. A number between 0 and 1.
transparent isotherm	An isotherm showing a linear spread of colors, instead of covering the highlighted parts of the image.
visual	Refers to the video mode of a IR camera, as opposed to the normal, thermographic mode. When a camera is in video mode it captures ordinary video images, while thermographic images are captured when the camera is in IR mode.

15 Thermographic measurement techniques

15.1 Introduction

An infrared camera measures and images the emitted infrared radiation from an object. The fact that radiation is a function of object surface temperature makes it possible for the camera to calculate and display this temperature.

However, the radiation measured by the camera does not only depend on the temperature of the object but is also a function of the emissivity. Radiation also originates from the surroundings and is reflected in the object. The radiation from the object and the reflected radiation will also be influenced by the absorption of the atmosphere.

To measure temperature accurately, it is therefore necessary to compensate for the effects of a number of different radiation sources. This is done on-line automatically by the camera. The following object parameters must, however, be supplied for the camera:

- The emissivity of the object
- The reflected temperature
- The distance between the object and the camera
- The relative humidity

15.2 Emissivity

The most important object parameter to set correctly is the emissivity which, in short, is a measure of how much radiation is emitted from the object, compared to that from a perfect blackbody.

Normally, object materials and surface treatments exhibit emissivity ranging from approximately 0.1 to 0.95. A highly polished (mirror) surface falls below 0.1, while an oxidized or painted surface has much higher emissivity. Oil-based paint, regardless of color in the visible spectrum, has an emissivity over 0.9 in the infrared. Human skin exhibits an emissivity close to 1.

Non-oxidized metals represent an extreme case of almost perfect opacity and high spectral reflexivity, which does not vary greatly with wavelength. Consequently, the emissivity of metals is low – only increasing with temperature. For non-metals, emissivity tends to be high, and decreases with temperature.

15.2.1 Finding the emissivity of an object

15.2.1.1 Using a thermocouple

Select a reference point and measure its temperature using a thermocouple. Alter the emissivity until the temperature measured by the camera agrees with the thermocouple reading. This is the emissivity value of the reference object. However, the temperature of the reference object must not be too close to the ambient temperature for this to work.

15.2.1.2 Using reference emissivity

A tape or paint of a known emissivity should be put onto the object. Measure the temperature of the tape/paint using the camera, setting emissivity to the correct value. Note the temperature. Alter emissivity, until the area with the unknown emissivity adjacent to the tape/paint has the same temperature reading. The emissivity value can now be read. The temperature of the reference object must not be too close to the ambient temperature for this to work either.

15.3 Reflected ambient temperature

This parameter is used to compensate for the radiation reflected in the object and the radiation emitted from the atmosphere between the camera and the object.

If the emissivity is low, the distance very long and the object temperature relatively close to that of the ambient it will be important to set and compensate for the ambient temperature correctly.

16 History of infrared technology

Less than 200 years ago the existence of the infrared portion of the electromagnetic spectrum wasn't even suspected. The original significance of the infrared spectrum, or simply 'the infrared' as it is often called, as a form of heat radiation is perhaps less obvious today than it was at the time of its discovery by Herschel in 1800.

10398703;1

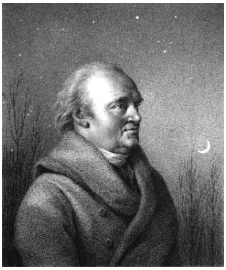

Figure 16.1 Sir William Herschel (1738–1822)

The discovery was made accidentally during the search for a new optical material. Sir William Herschel – Royal Astronomer to King George III of England, and already famous for his discovery of the planet Uranus – was searching for an optical filter material to reduce the brightness of the sun's image in telescopes during solar observations. While testing different samples of colored glass which gave similar reductions in brightness he was intrigued to find that some of the samples passed very little of the sun's heat, while others passed so much heat that he risked eye damage after only a few seconds' observation.

Herschel was soon convinced of the necessity of setting up a systematic experiment, with the objective of finding a single material that would give the desired reduction in brightness as well as the maximum reduction in heat. He began the experiment by actually repeating Newton's prism experiment, but looking for the heating effect rather than the visual distribution of intensity in the spectrum. He first blackened the bulb of a sensitive mercury-in-glass thermometer with ink, and with this as his radiation detector he proceeded to test the heating effect of the various colors of the spectrum formed on the top of a table by passing sunlight through a glass prism. Other thermometers, placed outside the sun's rays, served as controls.

As the blackened thermometer was moved slowly along the colors of the spectrum, the temperature readings showed a steady increase from the violet end to the red end. This was not entirely unexpected, since the Italian researcher, Landriani,

in a similar experiment in 1777 had observed much the same effect. It was Herschel, however, who was the first to recognize that there must be a point where the heating effect reaches a maximum, and that measurements confined to the visible portion of the spectrum failed to locate this point.

10398903;1

Figure 16.2 Marsilio Landriani (1746–1815)

Moving the thermometer into the dark region beyond the red end of the spectrum, Herschel confirmed that the heating continued to increase. The maximum point, when he found it, lay well beyond the red end – in what is known today as the 'infrared wavelengths'.

When Herschel revealed his discovery, he referred to this new portion of the electromagnetic spectrum as the 'thermometrical spectrum'. The radiation itself he sometimes referred to as 'dark heat', or simply 'the invisible rays'. Ironically, and contrary to popular opinion, it wasn't Herschel who originated the term 'infrared'. The word only began to appear in print around 75 years later, and it is still unclear who should receive credit as the originator.

Herschel's use of glass in the prism of his original experiment led to some early controversies with his contemporaries about the actual existence of the infrared wavelengths. Different investigators, in attempting to confirm his work, used various types of glass indiscriminately, having different transparencies in the infrared. Through his later experiments, Herschel was aware of the limited transparency of glass to the newly-discovered thermal radiation, and he was forced to conclude that optics for the infrared would probably be doomed to the use of reflective elements exclusively (i.e. plane and curved mirrors). Fortunately, this proved to be true only until 1830, when the Italian investigator, Melloni, made his great discovery that naturally occurring rock salt (NaCl) – which was available in large enough natural crystals to be made into lenses and prisms – is remarkably transparent to the infrared. The result was that rock salt became the principal infrared optical material, and remained so for the next hundred years, until the art of synthetic crystal growing was mastered in the 1930's.

10399103;1

Figure 16.3 Macedonio Melloni (1798–1854)

Thermometers, as radiation detectors, remained unchallenged until 1829, the year Nobili invented the thermocouple. (Herschel's own thermometer could be read to 0.2 °C (0.036 °F), and later models were able to be read to 0.05 °C (0.09 °F)). Then a breakthrough occurred; Melloni connected a number of thermocouples in series to form the first thermopile. The new device was at least 40 times as sensitive as the best thermometer of the day for detecting heat radiation – capable of detecting the heat from a person standing three meters away.

The first so-called 'heat-picture' became possible in 1840, the result of work by Sir John Herschel, son of the discoverer of the infrared and a famous astronomer in his own right. Based upon the differential evaporation of a thin film of oil when exposed to a heat pattern focused upon it, the thermal image could be seen by reflected light where the interference effects of the oil film made the image visible to the eye. Sir John also managed to obtain a primitive record of the thermal image on paper, which he called a 'thermograph'.

10399003;1

Figure 16.4 Samuel P. Langley (1834–1906)

The improvement of infrared-detector sensitivity progressed slowly. Another major breakthrough, made by Langley in 1880, was the invention of the bolometer.

This consisted of a thin blackened strip of platinum connected in one arm of a Wheatstone bridge circuit upon which the infrared radiation was focused and to which a sensitive galvanometer responded. This instrument is said to have been able to detect the heat from a cow at a distance of 400 meters.

An English scientist, Sir James Dewar, first introduced the use of liquefied gases as cooling agents (such as liquid nitrogen with a temperature of -196 °C (-320.8 °F)) in low temperature research. In 1892 he invented a unique vacuum insulating container in which it is possible to store liquefied gases for entire days. The common 'thermos bottle', used for storing hot and cold drinks, is based upon his invention.

Between the years 1900 and 1920, the inventors of the world 'discovered' the infrared. Many patents were issued for devices to detect personnel, artillery, aircraft, ships – and even icebergs. The first operating systems, in the modern sense, began to be developed during the 1914–18 war, when both sides had research programs devoted to the military exploitation of the infrared. These programs included experimental systems for enemy intrusion/detection, remote temperature sensing, secure communications, and 'flying torpedo' guidance. An infrared search system tested during this period was able to detect an approaching airplane at a distance of 1.5 km (0.94 miles), or a person more than 300 meters (984 ft.) away.

The most sensitive systems up to this time were all based upon variations of the bolometer idea, but the period between the two wars saw the development of two revolutionary new infrared detectors: the image converter and the photon detector. At first, the image converter received the greatest attention by the military, because it enabled an observer for the first time in history to literally 'see in the dark'. However, the sensitivity of the image converter was limited to the near infrared wavelengths, and the most interesting military targets (i.e. enemy soldiers) had to be illuminated by infrared search beams. Since this involved the risk of giving away the observer's position to a similarly-equipped enemy observer, it is understandable that military interest in the image converter eventually faded.

The tactical military disadvantages of so-called 'active' (i.e. search beam-equipped) thermal imaging systems provided impetus following the 1939–45 war for extensive secret military infrared-research programs into the possibilities of developing 'passive' (no search beam) systems around the extremely sensitive photon detector. During this period, military secrecy regulations completely prevented disclosure of the status of infrared-imaging technology. This secrecy only began to be lifted in the middle of the 1950's, and from that time adequate thermal-imaging devices finally began to be available to civilian science and industry.

17 Theory of thermography

17.1 Introduction

The subjects of infrared radiation and the related technique of thermography are still new to many who will use an infrared camera. In this section the theory behind thermography will be given.

17.2 The electromagnetic spectrum

The electromagnetic spectrum is divided arbitrarily into a number of wavelength regions, called *bands*, distinguished by the methods used to produce and detect the radiation. There is no fundamental difference between radiation in the different bands of the electromagnetic spectrum. They are all governed by the same laws and the only differences are those due to differences in wavelength.

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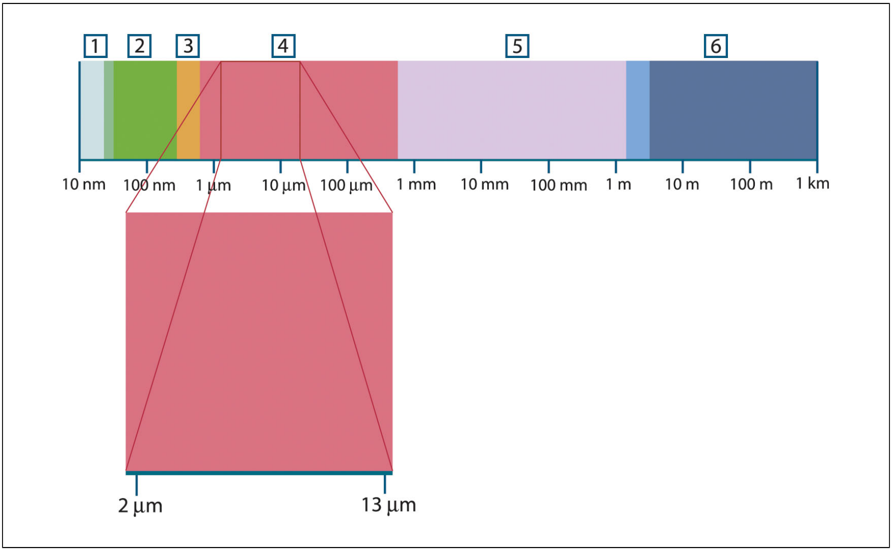

Figure 17.1 The electromagnetic spectrum. **1:** X-ray; **2:** UV; **3:** Visible; **4:** IR; **5:** Microwaves; **6:** Radiowaves.

Thermography makes use of the infrared spectral band. At the short-wavelength end the boundary lies at the limit of visual perception, in the deep red. At the long-wavelength end it merges with the microwave radio wavelengths, in the millimeter range.

The infrared band is often further subdivided into four smaller bands, the boundaries of which are also arbitrarily chosen. They include: the *near infrared*

(0.75–3 μm), the *middle infrared* (3–6 μm), the *far infrared* (6–15 μm) and the *extreme infrared* (15–100 μm). Although the wavelengths are given in μm (micrometers), other units are often still used to measure wavelength in this spectral region, *e.g.* nanometer (nm) and Ångström (Å).

The relationships between the different wavelength measurements is:

$$10\ 000\ \text{Å} = 1\ 000\ \text{nm} = 1\ \mu = 1\ \mu\text{m}$$

17.3 Blackbody radiation

A blackbody is defined as an object which absorbs all radiation that impinges on it at any wavelength. The apparent misnomer *black* relating to an object emitting radiation is explained by Kirchhoff's Law (after *Gustav Robert Kirchhoff*, 1824–1887), which states that a body capable of absorbing all radiation at any wavelength is equally capable in the emission of radiation.

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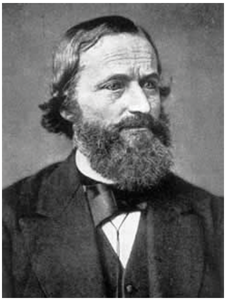

Figure 17.2 Gustav Robert Kirchhoff (1824–1887)

The construction of a blackbody source is, in principle, very simple. The radiation characteristics of an aperture in an isotherm cavity made of an opaque absorbing material represents almost exactly the properties of a blackbody. A practical application of the principle to the construction of a perfect absorber of radiation consists of a box that is light tight except for an aperture in one of the sides. Any radiation which then enters the hole is scattered and absorbed by repeated reflections so only an infinitesimal fraction can possibly escape. The blackness which is obtained at the aperture is nearly equal to a blackbody and almost perfect for all wavelengths.

By providing such an isothermal cavity with a suitable heater it becomes what is termed a *cavity radiator*. An isothermal cavity heated to a uniform temperature generates blackbody radiation, the characteristics of which are determined solely by the temperature of the cavity. Such cavity radiators are commonly used as

sources of radiation in temperature reference standards in the laboratory for calibrating thermographic instruments, such as a FLIR Systems camera for example.

If the temperature of blackbody radiation increases to more than 525 °C (977 °F), the source begins to be visible so that it appears to the eye no longer black. This is the incipient red heat temperature of the radiator, which then becomes orange or yellow as the temperature increases further. In fact, the definition of the so-called *color temperature* of an object is the temperature to which a blackbody would have to be heated to have the same appearance.

Now consider three expressions that describe the radiation emitted from a blackbody.

17.3.1 Planck's law

10399203;1

Figure 17.3 Max Planck (1858–1947)

Max Planck (1858–1947) was able to describe the spectral distribution of the radiation from a blackbody by means of the following formula:

$$W_{\lambda b} = \frac{2\pi hc^3}{\lambda^5 \left(e^{hc/\lambda kT} - 1\right)} \times 10^{-6} \left[Watt/m^2 \mu m\right]$$

where:

$W_{\lambda b}$	Blackbody spectral radiant emittance at wavelength λ.
c	Velocity of light = 3 × 10^8 m/s
h	Planck's constant = 6.6 × 10^{-34} Joule sec.
k	Boltzmann's constant = 1.4 × 10^{-23} Joule/K.
T	Absolute temperature (K) of a blackbody.

λ	Wavelength (μm).

NOTE: The factor 10^{-6} is used since spectral emittance in the curves is expressed in Watt/m^{2}m. If the factor is excluded, the dimension will be Watt/m^{2}μm.

Planck's formula, when plotted graphically for various temperatures, produces a family of curves. Following any particular Planck curve, the spectral emittance is zero at $\lambda = 0$, then increases rapidly to a maximum at a wavelength λ_{max} and after passing it approaches zero again at very long wavelengths. The higher the temperature, the shorter the wavelength at which maximum occurs.

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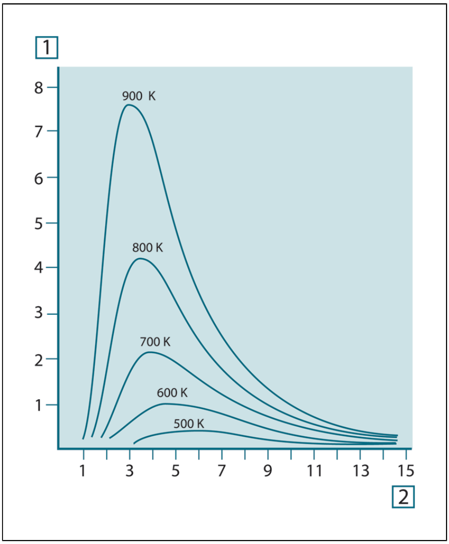

Figure 17.4 Blackbody spectral radiant emittance according to Planck's law, plotted for various absolute temperatures. **1:** Spectral radiant emittance (W/cm^2 × 10^3(μm)); **2:** Wavelength (μm)

17.3.2 Wien's displacement law

By differentiating Planck's formula with respect to λ, and finding the maximum, we have:

$$\lambda_{\max} = \frac{2898}{T}[\mu m]$$

This is Wien's formula (after *Wilhelm Wien*, 1864–1928), which expresses mathematically the common observation that colors vary from red to orange or yellow as the temperature of a thermal radiator increases. The wavelength of the color is the same as the wavelength calculated for λ_{max}. A good approximation of the value of λ_{max} for a given blackbody temperature is obtained by applying the rule-

of-thumb 3 000/T μm. Thus, a very hot star such as Sirius (11 000 K), emitting bluish-white light, radiates with the peak of spectral radiant emittance occurring within the invisible ultraviolet spectrum, at wavelength 0.27 μm.

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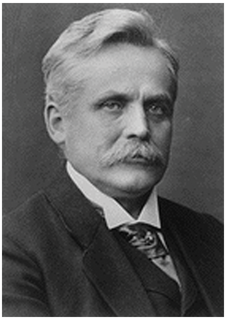

Figure 17.5 Wilhelm Wien (1864–1928)

The sun (approx. 6 000 K) emits yellow light, peaking at about 0.5 μm in the middle of the visible light spectrum.

At room temperature (300 K) the peak of radiant emittance lies at 9.7 μm, in the far infrared, while at the temperature of liquid nitrogen (77 K) the maximum of the almost insignificant amount of radiant emittance occurs at 38 μm, in the extreme infrared wavelengths.

10327203;3

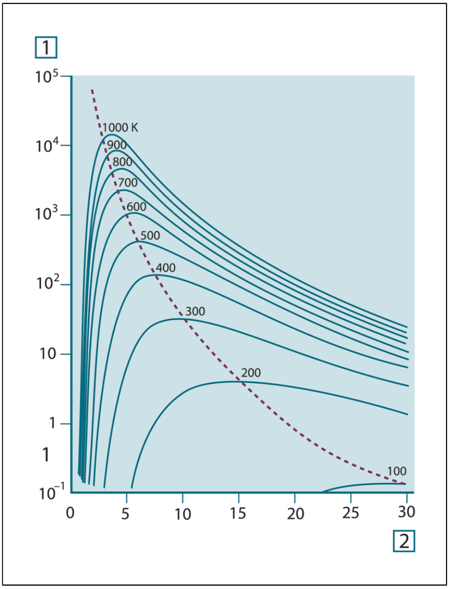

Figure 17.6 Planckian curves plotted on semi-log scales from 100 K to 1000 K. The dotted line represents the locus of maximum radiant emittance at each temperature as described by Wien's displacement law. **1:** Spectral radiant emittance (W/cm2 (μm)); **2:** Wavelength (μm).

17.3.3 Stefan-Boltzmann's law

By integrating Planck's formula from λ = 0 to λ = ∞, we obtain the total radiant emittance (W_b) of a blackbody:

$$W_b = \sigma T^4 \ \ [\mathrm{Watt/m^2}]$$

This is the Stefan-Boltzmann formula (after *Josef Stefan*, 1835–1893, and *Ludwig Boltzmann*, 1844–1906), which states that the total emissive power of a blackbody is proportional to the fourth power of its absolute temperature. Graphically, W_b represents the area below the Planck curve for a particular temperature. It can be shown that the radiant emittance in the interval λ = 0 to λ_{max} is only 25 % of the total, which represents about the amount of the sun's radiation which lies inside the visible light spectrum.

10399303;1

Figure 17.7 Josef Stefan (1835–1893), and Ludwig Boltzmann (1844–1906)

Using the Stefan-Boltzmann formula to calculate the power radiated by the human body, at a temperature of 300 K and an external surface area of approx. 2 m^2, we obtain 1 kW. This power loss could not be sustained if it were not for the compensating absorption of radiation from surrounding surfaces, at room temperatures which do not vary too drastically from the temperature of the body – or, of course, the addition of clothing.

17.3.4 Non-blackbody emitters

So far, only blackbody radiators and blackbody radiation have been discussed. However, real objects almost never comply with these laws over an extended wavelength region – although they may approach the blackbody behavior in certain spectral intervals. For example, a certain type of white paint may appear perfectly *white* in the visible light spectrum, but becomes distinctly *gray* at about 2 μm, and beyond 3 μm it is almost *black*.

There are three processes which can occur that prevent a real object from acting like a blackbody: a fraction of the incident radiation α may be absorbed, a fraction ρ may be reflected, and a fraction τ may be transmitted. Since all of these factors are more or less wavelength dependent, the subscript λ is used to imply the spectral dependence of their definitions. Thus:

- The spectral absorptance α_λ= the ratio of the spectral radiant power absorbed by an object to that incident upon it.
- The spectral reflectance ρ_λ = the ratio of the spectral radiant power reflected by an object to that incident upon it.
- The spectral transmittance τ_λ = the ratio of the spectral radiant power transmitted through an object to that incident upon it.

The sum of these three factors must always add up to the whole at any wavelength, so we have the relation:

$$\alpha_\lambda + \rho_\lambda + \tau_\lambda = 1$$

For opaque materials τ_λ = 0 and the relation simplifies to:

Publ. No. 1 557 945 Rev. a43 – ENGLISH (EN) – April 6, 2004

$$\alpha_\lambda + \rho_\lambda = 1$$

Another factor, called the emissivity, is required to describe the fraction ε of the radiant emittance of a blackbody produced by an object at a specific temperature. Thus, we have the definition:

The spectral emissivity ε_λ= the ratio of the spectral radiant power from an object to that from a blackbody at the same temperature and wavelength.

Expressed mathematically, this can be written as the ratio of the spectral emittance of the object to that of a blackbody as follows:

$$\varepsilon_\lambda = \frac{W_{\lambda o}}{W_{\lambda b}}$$

Generally speaking, there are three types of radiation source, distinguished by the ways in which the spectral emittance of each varies with wavelength.

- A blackbody, for which $\varepsilon_\lambda = \varepsilon = 1$
- A graybody, for which $\varepsilon_\lambda = \varepsilon$ = constant less than 1
- A selective radiator, for which ε varies with wavelength

According to Kirchhoff's law, for any material the spectral emissivity and spectral absorptance of a body are equal at any specified temperature and wavelength. That is:

$$\varepsilon_\lambda = \alpha_\lambda$$

From this we obtain, for an opaque material (since $\alpha_\lambda + \rho_\lambda = 1$):

$$\varepsilon_\lambda + \rho_\lambda = 1$$

For highly polished materials ε_λ approaches zero, so that for a perfectly reflecting material (*i.e.* a perfect mirror) we have:

$$\rho_\lambda = 1$$

For a graybody radiator, the Stefan-Boltzmann formula becomes:

$$W = \varepsilon\sigma T^4 \ [\mathrm{Watt/m^2}]$$

This states that the total emissive power of a graybody is the same as a blackbody at the same temperature reduced in proportion to the value of ε from the graybody.

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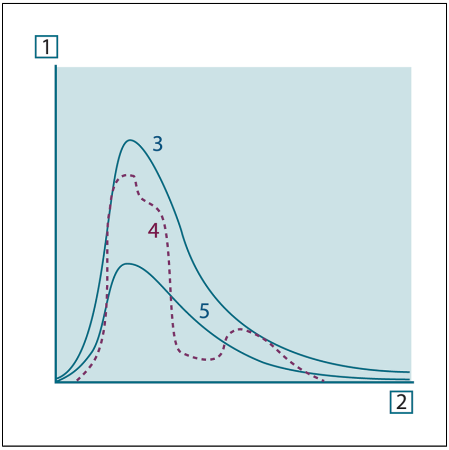

Figure 17.8 Spectral radiant emittance of three types of radiators. **1:** Spectral radiant emittance; **2:** Wavelength; **3:** Blackbody; **4:** Selective radiator; **5:** Graybody.

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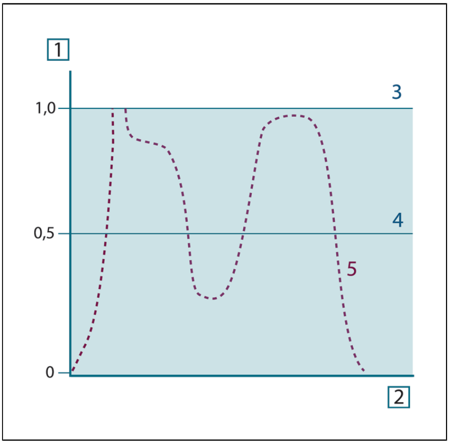

Figure 17.9 Spectral emissivity of three types of radiators. **1:** Spectral emissivity; **2:** Wavelength; **3:** Blackbody; **4:** Graybody; **5:** Selective radiator.

17.4 Infrared semi-transparent materials

Consider now a non-metallic, semi-transparent body – let us say, in the form of a thick flat plate of plastic material. When the plate is heated, radiation generated within its volume must work its way toward the surfaces through the material in which it is partially absorbed. Moreover, when it arrives at the surface, some of it is reflected back into the interior. The back-reflected radiation is again partially absorbed, but some of it arrives at the other surface, through which most of it escapes; part of it is reflected back again. Although the progressive reflections

become weaker and weaker they must all be added up when the total emittance of the plate is sought. When the resulting geometrical series is summed, the effective emissivity of a semi-transparent plate is obtained as:

$$\varepsilon_\lambda = \frac{(1-\rho_\lambda)(1-\tau_\lambda)}{1-\rho_\lambda\tau_\lambda}$$

When the plate becomes opaque this formula is reduced to the single formula:

$$\varepsilon_\lambda = 1-\rho_\lambda$$

This last relation is a particularly convenient one, because it is often easier to measure reflectance than to measure emissivity directly.

18 The measurement formula

As already mentioned, when viewing an object, the camera receives radiation not only from the object itself. It also collects radiation from the surroundings reflected via the object surface. Both these radiation contributions become attenuated to some extent by the atmosphere in the measurement path. To this comes a third radiation contribution from the atmosphere itself.

This description of the measurement situation, as illustrated in the figure below, is so far a fairly true description of the real conditions. What has been neglected could for instance be sun light scattering in the atmosphere or stray radiation from intense radiation sources outside the field of view. Such disturbances are difficult to quantify, however, in most cases they are fortunately small enough to be neglected. In case they are not negligible, the measurement configuration is likely to be such that the risk for disturbance is obvious, at least to a trained operator. It is then his responsibility to modify the measurement situation to avoid the disturbance e.g. by changing the viewing direction, shielding off intense radiation sources etc.

Accepting the description above, we can use the figure below to derive a formula for the calculation of the object temperature from the calibrated camera output.

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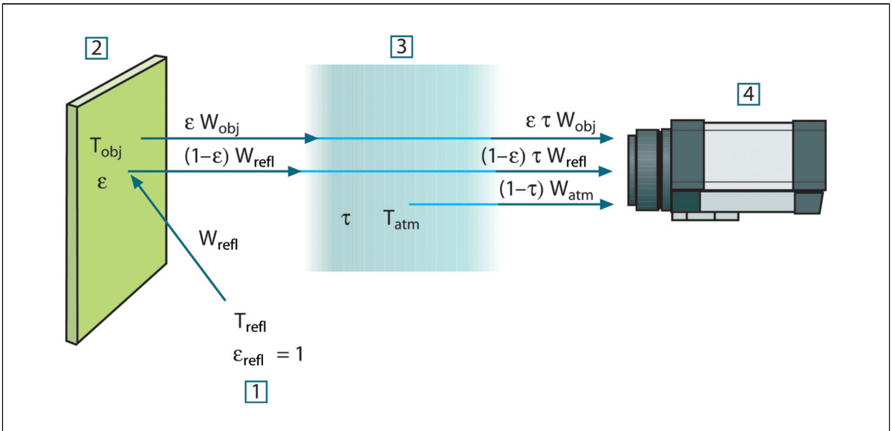

Figure 18.1 A schematic representation of the general thermographic measurement situation.**1:** Surroundings; **2:** Object; **3:** Atmosphere; **4:** Camera

Assume that the received radiation power W from a blackbody source of temperature T_{source} on short distance generates a camera output signal U_{source} that is proportional to the power input (power linear camera). We can then write (Equation 1):

$$U_{source} = CW(T_{source})$$

or, with simplified notation:

$$U_{source} = CW_{source}$$

where C is a constant.

Should the source be a graybody with emittance ε, the received radiation would consequently be εW_{source}.

We are now ready to write the three collected radiation power terms:

1 – Emission from the object = $\varepsilon\tau W_{obj}$, where ε is the emittance of the object and τ is the transmittance of the atmosphere. The object temperature is T_{obj}.

2 – Reflected emission from ambient sources = $(1 - \varepsilon)\tau W_{refl}$, where $(1 - \varepsilon)$ is the reflectance of the object. The ambient sources have the temperature T_{refl}.

It has here been assumed that the temperature T_{refl} is the same for all emitting surfaces within the halfsphere seen from a point on the object surface. This is of course sometimes a simplification of the true situation. It is, however, a necessary simplification in order to derive a workable formula, and T_{refl} can – at least theoretically – be given a value that represents an efficient temperature of a complex surrounding.

Note also that we have assumed that the emittance for the surroundings = 1. This is correct in accordance with Kirchhoff's law: All radiation impinging on the surrounding surfaces will eventually be absorbed by the same surfaces. Thus the emittance = 1. (Note though that the latest discussion requires the complete sphere around the object to be considered.)

3 – Emission from the atmosphere = $(1 - \tau)\tau W_{atm}$, where $(1 - \tau)$ is the emittance of the atmosphere. The temperature of the atmosphere is T_{atm}.

The total received radiation power can now be written (Equation 2):

$$W_{tot} = \varepsilon\tau W_{obj} + (1 - \varepsilon)\tau W_{refl} + (1 - \tau)W_{atm}$$

We multiply each term by the constant C of Equation 1 and replace the CW products by the corresponding U according to the same equation, and get (Equation 3):

$$U_{tot} = \varepsilon\tau U_{obj} + (1 - \varepsilon)\tau U_{refl} + (1 - \tau)U_{atm}$$

Solve Equation 3 for U_{obj} (Equation 4):

$$U_{obj} = \frac{1}{\varepsilon\tau} U_{tot} - \frac{1-\varepsilon}{\varepsilon} U_{refl} - \frac{1-\tau}{\varepsilon\tau} U_{atm}$$

This is the general measurement formula used in all the FLIR Systems thermographic equipment. The voltages of the formula are:

Figure 18.2 Voltages

U_{obj}	Calculated camera output voltage for a blackbody of temperature T_{obj} i.e. a voltage that can be directly converted into true requested object temperature.
U_{tot}	Measured camera output voltage for the actual case.
U_{refl}	Theoretical camera output voltage for a blackbody of temperature T_{refl} according to the calibration.
U_{atm}	Theoretical camera output voltage for a blackbody of temperature T_{atm} according to the calibration.

The operator has to supply a number of parameter values for the calculation:

- the object emittance ε,
- the relative humidity,
- T_{atm}
- object distance (D_{obj})
- the (effective) temperature of the object surroundings, or the reflected ambient temperature T_{refl}, and
- the temperature of the atmosphere T_{atm}

This task could sometimes be a heavy burden for the operator since there are normally no easy ways to find accurate values of emittance and atmospheric transmittance for the actual case. The two temperatures are normally less of a problem provided the surroundings do not contain large and intense radiation sources.

A natural question in this connection is: How important is it to know the right values of these parameters? It could though be of interest to get a feeling for this problem already here by looking into some different measurement cases and compare the relative magnitudes of the three radiation terms. This will give indications about when it is important to use correct values of which parameters.

The figures below illustrates the relative magnitudes of the three radiation contributions for three different object temperatures, two emittances, and two spectral ranges: SW and LW. Remaining parameters have the following fixed values:

- τ = 0.88

- T_{refl} = +20 °C (+68 °F)
- T_{atm} = +20 °C (+68 °F)

It is obvious that measurement of low object temperatures are more critical than measuring high temperatures since the 'disturbing' radiation sources are relatively much stronger in the first case. Should also the object emittance be low, the situation would be still more difficult.

We have finally to answer a question about the importance of being allowed to use the calibration curve above the highest calibration point, what we call extrapolation. Imagine that we in a certain case measure U_{tot} = 4.5 volts. The highest calibration point for the camera was in the order of 4.1 volts, a value unknown to the operator. Thus, even if the object happened to be a blackbody, i.e. $U_{obj} = U_{tot}$, we are actually performing extrapolation of the calibration curve when converting 4.5 volts into temperature.

Let us now assume that the object is not black, it has an emittance of 0.75, and the transmittance is 0.92. We also assume that the two second terms of Equation 4 amount to 0.5 volts together. Computation of U_{obj} by means of Equation 4 then results in U_{obj} = 4.5 / 0.75 / 0.92 – 0.5 = 6.0. This is a rather extreme extrapolation, particularly when considering that the video amplifier might limit the output to 5 volts! Note, though, that the application of the calibration curve is a theoretical procedure where no electronic or other limitations exist. We trust that if there had been no signal limitations in the camera, and if it had been calibrated far beyond 5 volts, the resulting curve would have been very much the same as our real curve extrapolated beyond 4.1 volts, provided the calibration algorithm is based on radiation physics, like the FLIR Systems algorithm. Of course there must be a limit to such extrapolations.

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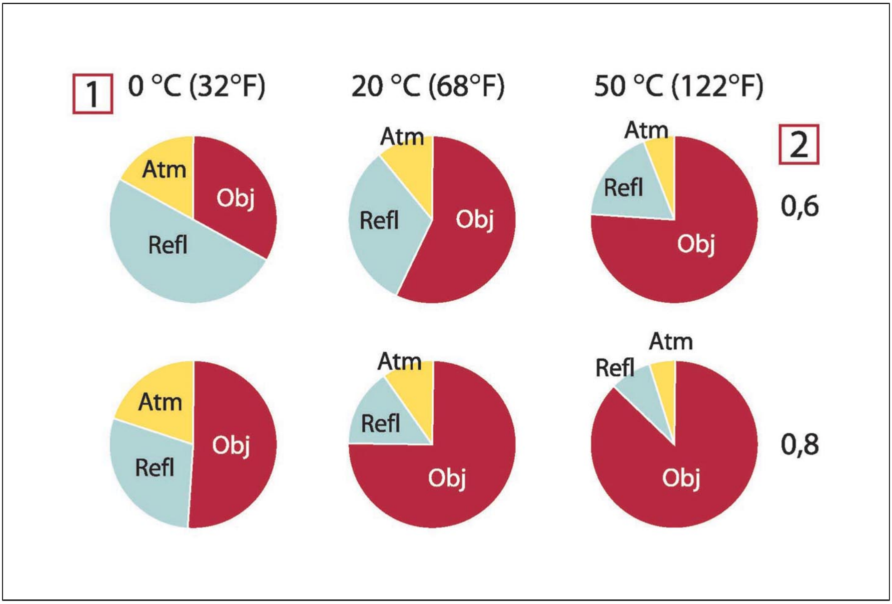

Figure 18.3 Relative magnitudes of radiation sources under varying measurement conditions (SW camera). **1:** Object temperature; **2:** Emittance; **Obj:** Object radiation; **Refl:** Reflected radiation; **Atm:** atmosphere radiation. Fixed parameters: $\tau = 0.88$; $T_{refl} = 20$ °C (+68 °F); $T_{atm} = 20$ °C (+68 °F).

10400703;2

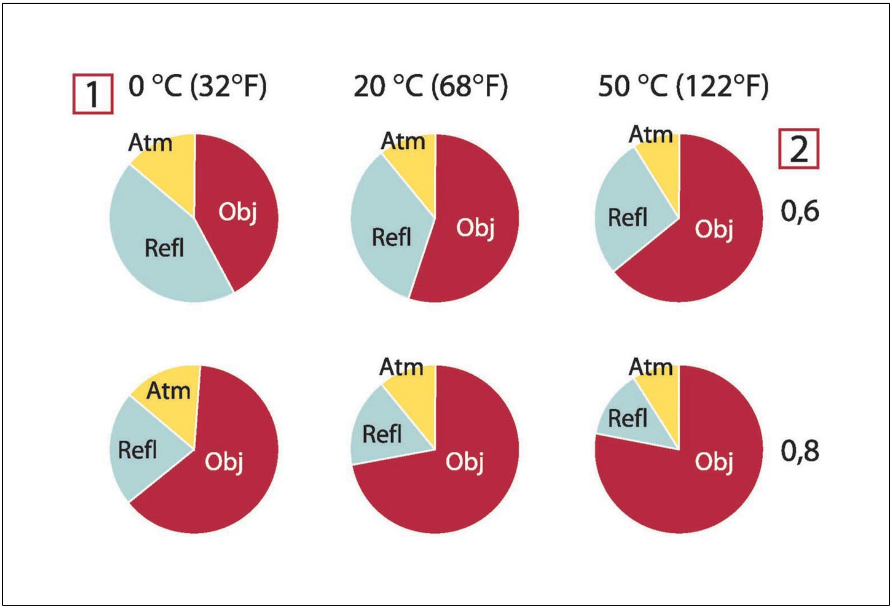

Figure 18.4 Relative magnitudes of radiation sources under varying measurement conditions (LW camera). **1:** Object temperature; **2:** Emittance; **Obj:** Object radiation; **Refl:** Reflected radiation; **Atm:** atmosphere radiation. Fixed parameters: $\tau = 0.88$; $T_{refl} = 20$ °C (+68 °F); $T_{atm} = 20$ °C (+68 °F).

19 Emissivity tables

This section presents a compilation of emissivity data from the infrared literature and FLIR Systems's own measurements.

19.1 References

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19.2 Tables

Figure 19.1 **T:** Total spectrum; **SW:** 2–5 µm; **LW:** 8–14 µm, **LLW:** 6.5–20 µm; **1:** Material; **2:** Specification; **3:** Temperature in °C; **4:** Spectrum; **5:** Emissivity: **6:** Reference

1	**2**	**3**	**4**	**5**	**6**
Aluminum	anodized, black, dull	70	LW	0.95	9
Aluminum	anodized, black, dull	70	SW	0.67	9

1	2	3	4	5	6
Aluminum	anodized, light gray, dull	70	LW	0.97	9
Aluminum	anodized, light gray, dull	70	SW	0.61	9
Aluminum	anodized sheet	100	T	0.55	2
Aluminum	as received, plate	100	T	0.09	4
Aluminum	as received, sheet	100	T	0.09	2
Aluminum	cast, blast cleaned	70	LW	0.46	9
Aluminum	cast, blast cleaned	70	SW	0.47	9
Aluminum	dipped in HNO_3, plate	100	T	0.05	4
Aluminum	foil	27	3 µm	0.09	3
Aluminum	foil	27	10 µm	0.04	3
Aluminum	oxidized, strongly	50–500	T	0.2–0.3	1
Aluminum	polished	50–100	T	0.04–0.06	1
Aluminum	polished, sheet	100	T	0.05	2
Aluminum	polished plate	100	T	0.05	4
Aluminum	roughened	27	3 µm	0.28	3
Aluminum	roughened	27	10 µm	0.18	3
Aluminum	rough surface	20–50	T	0.06–0.07	1
Aluminum	sheet, 4 samples differently scratched	70	LW	0.03–0.06	9
Aluminum	sheet, 4 samples differently scratched	70	SW	0.05–0.08	9
Aluminum	vacuum deposited	20	T	0.04	2

1	2	3	4	5	6
Aluminum	weathered, heavily	17	SW	0.83–0.94	5
Aluminum bronze		20	T	0.60	1
Aluminum hydroxide	powder		T	0.28	1
Aluminum oxide	activated, powder		T	0.46	1
Aluminum oxide	pure, powder (alumina)		T	0.16	1
Asbestos	board	20	T	0.96	1
Asbestos	fabric		T	0.78	1
Asbestos	floor tile	35	SW	0.94	7
Asbestos	paper	40–400	T	0.93–0.95	1
Asbestos	powder		T	0.40–0.60	1
Asbestos	slate	20	T	0.96	1
Asphalt paving		4	LLW	0.967	8
Brass	dull, tarnished	20–350	T	0.22	1
Brass	oxidized	70	SW	0.04–0.09	9
Brass	oxidized	70	LW	0.03–0.07	9
Brass	oxidized	100	T	0.61	2
Brass	oxidized at 600 °C	200–600	T	0.59–0.61	1
Brass	polished	200	T	0.03	1
Brass	polished, highly	100	T	0.03	2
Brass	rubbed with 80-grit emery	20	T	0.20	2
Brass	sheet, rolled	20	T	0.06	1
Brass	sheet, worked with emery	20	T	0.2	1

1	2	3	4	5	6
Brick	alumina	17	SW	0.68	5
Brick	common	17	SW	0.86–0.81	5
Brick	Dinas silica, glazed, rough	1100	T	0.85	1
Brick	Dinas silica, refractory	1000	T	0.66	1
Brick	Dinas silica, unglazed, rough	1000	T	0.80	1
Brick	firebrick	17	SW	0.68	5
Brick	fireclay	20	T	0.85	1
Brick	fireclay	1000	T	0.75	1
Brick	fireclay	1200	T	0.59	1
Brick	masonry	35	SW	0.94	7
Brick	masonry, plastered	20	T	0.94	1
Brick	red, common	20	T	0.93	2
Brick	red, rough	20	T	0.88–0.93	1
Brick	refractory, corundum	1000	T	0.46	1
Brick	refractory, magnesite	1000–1300	T	0.38	1
Brick	refractory, strongly radiating	500–1000	T	0.8–0.9	1
Brick	refractory, weakly radiating	500–1000	T	0.65–0.75	1
Brick	silica, 95 % SiO_2	1230	T	0.66	1
Brick	sillimanite, 33 % SiO_2, 64 % Al_2O_3	1500	T	0.29	1
Brick	waterproof	17	SW	0.87	5
Bronze	phosphor bronze	70	LW	0.06	9

1	2	3	4	5	6
Bronze	phosphor bronze	70	SW	0.08	9
Bronze	polished	50	T	0.1	1
Bronze	porous, rough	50–150	T	0.55	1
Bronze	powder		T	0.76–0.80	1
Carbon	candle soot	20	T	0.95	2
Carbon	charcoal powder		T	0.96	1
Carbon	graphite, filed surface	20	T	0.98	2
Carbon	graphite powder		T	0.97	1
Carbon	lampblack	20–400	T	0.95–0.97	1
Chipboard	untreated	20	SW	0.90	6
Chromium	polished	50	T	0.10	1
Chromium	polished	500–1000	T	0.28–0.38	1
Clay	fired	70	T	0.91	1
Cloth	black	20	T	0.98	1
Concrete		20	T	0.92	2
Concrete	dry	36	SW	0.95	7
Concrete	rough	17	SW	0.97	5
Concrete	walkway	5	LLW	0.974	8
Copper	commercial, burnished	20	T	0.07	1
Copper	electrolytic, carefully polished	80	T	0.018	1
Copper	electrolytic, polished	–34	T	0.006	4
Copper	molten	1100–1300	T	0.13–0.15	1
Copper	oxidized	50	T	0.6–0.7	1
Copper	oxidized, black	27	T	0.78	4

1	2	3	4	5	6
Copper	oxidized, heavily	20	T	0.78	2
Copper	oxidized to blackness		T	0.88	1
Copper	polished	50–100	T	0.02	1
Copper	polished	100	T	0.03	2
Copper	polished, commercial	27	T	0.03	4
Copper	polished, mechanical	22	T	0.015	4
Copper	pure, carefully prepared surface	22	T	0.008	4
Copper	scraped	27	T	0.07	4
Copper dioxide	powder		T	0.84	1
Copper oxide	red, powder		T	0.70	1
Ebonite			T	0.89	1
Emery	coarse	80	T	0.85	1
Enamel		20	T	0.9	1
Enamel	lacquer	20	T	0.85–0.95	1
Fiber board	hard, untreated	20	SW	0.85	6
Fiber board	masonite	70	LW	0.88	9
Fiber board	masonite	70	SW	0.75	9
Fiber board	particle board	70	LW	0.89	9
Fiber board	particle board	70	SW	0.77	9
Fiber board	porous, untreated	20	SW	0.85	6
Gold	polished	130	T	0.018	1
Gold	polished, carefully	200–600	T	0.02–0.03	1
Gold	polished, highly	100	T	0.02	2

1	2	3	4	5	6
Granite	polished	20	LLW	0.849	8
Granite	rough	21	LLW	0.879	8
Granite	rough, 4 different samples	70	LW	0.77–0.87	9
Granite	rough, 4 different samples	70	SW	0.95–0.97	9
Gypsum		20	T	0.8–0.9	1
Ice: See Water					
Iron, cast	casting	50	T	0.81	1
Iron, cast	ingots	1000	T	0.95	1
Iron, cast	liquid	1300	T	0.28	1
Iron, cast	machined	800–1000	T	0.60–0.70	1
Iron, cast	oxidized	38	T	0.63	4
Iron, cast	oxidized	100	T	0.64	2
Iron, cast	oxidized	260	T	0.66	4
Iron, cast	oxidized	538	T	0.76	4
Iron, cast	oxidized at 600 °C	200–600	T	0.64–0.78	1
Iron, cast	polished	38	T	0.21	4
Iron, cast	polished	40	T	0.21	2
Iron, cast	polished	200	T	0.21	1
Iron, cast	unworked	900–1100	T	0.87–0.95	1
Iron and steel	cold rolled	70	LW	0.09	9
Iron and steel	cold rolled	70	SW	0.20	9
Iron and steel	covered with red rust	20	T	0.61–0.85	1
Iron and steel	electrolytic	22	T	0.05	4
Iron and steel	electrolytic	100	T	0.05	4

1	2	3	4	5	6
Iron and steel	electrolytic	260	T	0.07	4
Iron and steel	electrolytic, carefully polished	175–225	T	0.05–0.06	1
Iron and steel	freshly worked with emery	20	T	0.24	1
Iron and steel	ground sheet	950–1100	T	0.55–0.61	1
Iron and steel	heavily rusted sheet	20	T	0.69	2
Iron and steel	hot rolled	20	T	0.77	1
Iron and steel	hot rolled	130	T	0.60	1
Iron and steel	oxidized	100	T	0.74	1
Iron and steel	oxidized	100	T	0.74	4
Iron and steel	oxidized	125–525	T	0.78–0.82	1
Iron and steel	oxidized	200	T	0.79	2
Iron and steel	oxidized	1227	T	0.89	4
Iron and steel	oxidized	200–600	T	0.80	1
Iron and steel	oxidized strongly	50	T	0.88	1
Iron and steel	oxidized strongly	500	T	0.98	1
Iron and steel	polished	100	T	0.07	2
Iron and steel	polished	400–1000	T	0.14–0.38	1
Iron and steel	polished sheet	750–1050	T	0.52–0.56	1
Iron and steel	rolled, freshly	20	T	0.24	1
Iron and steel	rolled sheet	50	T	0.56	1
Iron and steel	rough, plane surface	50	T	0.95–0.98	1
Iron and steel	rusted, heavily	17	SW	0.96	5
Iron and steel	rusted red, sheet	22	T	0.69	4
Iron and steel	rusty, red	20	T	0.69	1

1	2	3	4	5	6
Iron and steel	shiny, etched	150	T	0.16	1
Iron and steel	shiny oxide layer, sheet,	20	T	0.82	1
Iron and steel	wrought, carefully polished	40–250	T	0.28	1
Iron galvanized	heavily oxidized	70	LW	0.85	9
Iron galvanized	heavily oxidized	70	SW	0.64	9
Iron galvanized	sheet	92	T	0.07	4
Iron galvanized	sheet, burnished	30	T	0.23	1
Iron galvanized	sheet, oxidized	20	T	0.28	1
Iron tinned	sheet	24	T	0.064	4
Lacquer	3 colors sprayed on Aluminum	70	LW	0.92–0.94	9
Lacquer	3 colors sprayed on Aluminum	70	SW	0.50–0.53	9
Lacquer	Aluminum on rough surface	20	T	0.4	1
Lacquer	bakelite	80	T	0.83	1
Lacquer	black, dull	40–100	T	0.96–0.98	1
Lacquer	black, matte	100	T	0.97	2
Lacquer	black, shiny, sprayed on iron	20	T	0.87	1
Lacquer	heat–resistant	100	T	0.92	1
Lacquer	white	40–100	T	0.8–0.95	1
Lacquer	white	100	T	0.92	2
Lead	oxidized, gray	20	T	0.28	1
Lead	oxidized, gray	22	T	0.28	4
Lead	oxidized at 200 °C	200	T	0.63	1
Lead	shiny	250	T	0.08	1

1	2	3	4	5	6
Lead	unoxidized, polished	100	T	0.05	4
Lead red		100	T	0.93	4
Lead red, powder		100	T	0.93	1
Leather	tanned		T	0.75–0.80	1
Lime			T	0.3–0.4	1
Magnesium		22	T	0.07	4
Magnesium		260	T	0.13	4
Magnesium		538	T	0.18	4
Magnesium	polished	20	T	0.07	2
Magnesium powder			T	0.86	1
Molybdenum		600–1000	T	0.08–0.13	1
Molybdenum		1500–2200	T	0.19–0.26	1
Molybdenum	filament	700–2500	T	0.1–0.3	1
Mortar		17	SW	0.87	5
Mortar	dry	36	SW	0.94	7
Nichrome	rolled	700	T	0.25	1
Nichrome	sandblasted	700	T	0.70	1
Nichrome	wire, clean	50	T	0.65	1
Nichrome	wire, clean	500–1000	T	0.71–0.79	1
Nichrome	wire, oxidized	50–500	T	0.95–0.98	1
Nickel	bright matte	122	T	0.041	4
Nickel	commercially pure, polished	100	T	0.045	1
Nickel	commercially pure, polished	200–400	T	0.07–0.09	1
Nickel	electrolytic	22	T	0.04	4

1	2	3	4	5	6
Nickel	electrolytic	38	T	0.06	4
Nickel	electrolytic	260	T	0.07	4
Nickel	electrolytic	538	T	0.10	4
Nickel	electroplated, polished	20	T	0.05	2
Nickel	electroplated on iron, polished	22	T	0.045	4
Nickel	electroplated on iron, unpolished	20	T	0.11–0.40	1
Nickel	electroplated on iron, unpolished	22	T	0.11	4
Nickel	oxidized	200	T	0.37	2
Nickel	oxidized	227	T	0.37	4
Nickel	oxidized	1227	T	0.85	4
Nickel	oxidized at 600 °C	200–600	T	0.37–0.48	1
Nickel	polished	122	T	0.045	4
Nickel	wire	200–1000	T	0.1–0.2	1
Nickel oxide		500–650	T	0.52–0.59	1
Nickel oxide		1000–1250	T	0.75–0.86	1
Oil, lubricating	0.025 mm film	20	T	0.27	2
Oil, lubricating	0.050 mm film	20	T	0.46	2
Oil, lubricating	0.125 mm film	20	T	0.72	2
Oil, lubricating	film on Ni base: Ni base only	20	T	0.05	2
Oil, lubricating	thick coating	20	T	0.82	2
Paint	8 different colors and qualities	70	LW	0.92–0.94	9
Paint	8 different colors and qualities	70	SW	0.88–0.96	9

1	2	3	4	5	6
Paint	Aluminum, various ages	50–100	T	0.27–0.67	1
Paint	cadmium yellow		T	0.28–0.33	1
Paint	chrome green		T	0.65–0.70	1
Paint	cobalt blue		T	0.7–0.8	1
Paint	oil	17	SW	0.87	5
Paint	oil, black flat	20	SW	0.94	6
Paint	oil, black gloss	20	SW	0.92	6
Paint	oil, gray flat	20	SW	0.97	6
Paint	oil, gray gloss	20	SW	0.96	6
Paint	oil, various colors	100	T	0.92–0.96	1
Paint	oil based, average of 16 colors	100	T	0.94	2
Paint	plastic, black	20	SW	0.95	6
Paint	plastic, white	20	SW	0.84	6
Paper	4 different colors	70	LW	0.92–0.94	9
Paper	4 different colors	70	SW	0.68–0.74	9
Paper	black		T	0.90	1
Paper	black, dull		T	0.94	1
Paper	black, dull	70	LW	0.89	9
Paper	black, dull	70	SW	0.86	9
Paper	blue, dark		T	0.84	1
Paper	coated with black lacquer		T	0.93	1
Paper	green		T	0.85	1
Paper	red		T	0.76	1
Paper	white	20	T	0.7–0.9	1

1	2	3	4	5	6
Paper	white, 3 different glosses	70	LW	0.88–0.90	9
Paper	white, 3 different glosses	70	SW	0.76–0.78	9
Paper	white bond	20	T	0.93	2
Paper	yellow		T	0.72	1
Plaster		17	SW	0.86	5
Plaster	plasterboard, untreated	20	SW	0.90	6
Plaster	rough coat	20	T	0.91	2
Plastic	glass fibre laminate (printed circ. board)	70	LW	0.91	9
Plastic	glass fibre laminate (printed circ. board)	70	SW	0.94	9
Plastic	polyurethane isolation board	70	LW	0.55	9
Plastic	polyurethane isolation board	70	SW	0.29	9
Plastic	PVC, plastic floor, dull, structured	70	LW	0.93	9
Plastic	PVC, plastic floor, dull, structured	70	SW	0.94	9
Platinum		17	T	0.016	4
Platinum		22	T	0.03	4
Platinum		100	T	0.05	4
Platinum		260	T	0.06	4
Platinum		538	T	0.10	4
Platinum		1000–1500	T	0.14–0.18	1
Platinum		1094	T	0.18	4

1	2	3	4	5	6
Platinum	pure, polished	200–600	T	0.05–0.10	1
Platinum	ribbon	900–1100	T	0.12–0.17	1
Platinum	wire	50–200	T	0.06–0.07	1
Platinum	wire	500–1000	T	0.10–0.16	1
Platinum	wire	1400	T	0.18	1
Porcelain	glazed	20	T	0.92	1
Porcelain	white, shiny		T	0.70–0.75	1
Rubber	hard	20	T	0.95	1
Rubber	soft, gray, rough	20	T	0.95	1
Sand			T	0.60	1
Sand		20	T	0.90	2
Sandstone	polished	19	LLW	0.909	8
Sandstone	rough	19	LLW	0.935	8
Silver	polished	100	T	0.03	2
Silver	pure, polished	200–600	T	0.02–0.03	1
Skin	human	32	T	0.98	2
Slag	boiler	0–100	T	0.97–0.93	1
Slag	boiler	200–500	T	0.89–0.78	1
Slag	boiler	600–1200	T	0.76–0.70	1
Slag	boiler	1400–1800	T	0.69–0.67	1
Snow: See Water					
Soil	dry	20	T	0.92	2
Soil	saturated with water	20	T	0.95	2
Stainless steel	alloy, 8 % Ni, 18 % Cr	500	T	0.35	1
Stainless steel	rolled	700	T	0.45	1

1	2	3	4	5	6
Stainless steel	sandblasted	700	T	0.70	1
Stainless steel	sheet, polished	70	LW	0.14	9
Stainless steel	sheet, polished	70	SW	0.18	9
Stainless steel	sheet, untreated, somewhat scratched	70	LW	0.28	9
Stainless steel	sheet, untreated, somewhat scratched	70	SW	0.30	9
Stainless steel	type 18-8, buffed	20	T	0.16	2
Stainless steel	type 18-8, oxidized at 800 °C	60	T	0.85	2
Stucco	rough, lime	10–90	T	0.91	1
Styrofoam	insulation	37	SW	0.60	7
Tar			T	0.79–0.84	1
Tar	paper	20	T	0.91–0.93	1
Tile	glazed	17	SW	0.94	5
Tin	burnished	20–50	T	0.04–0.06	1
Tin	tin–plated sheet iron	100	T	0.07	2
Titanium	oxidized at 540 °C	200	T	0.40	1
Titanium	oxidized at 540 °C	500	T	0.50	1
Titanium	oxidized at 540 °C	1000	T	0.60	1
Titanium	polished	200	T	0.15	1
Titanium	polished	500	T	0.20	1
Titanium	polished	1000	T	0.36	1
Tungsten		200	T	0.05	1
Tungsten		600–1000	T	0.1–0.16	1

1	2	3	4	5	6
Tungsten		1500–2200	T	0.24–0.31	1
Tungsten	filament	3300	T	0.39	1
Varnish	flat	20	SW	0.93	6
Varnish	on oak parquet floor	70	LW	0.90–0.93	9
Varnish	on oak parquet floor	70	SW	0.90	9
Wallpaper	slight pattern, light gray	20	SW	0.85	6
Wallpaper	slight pattern, red	20	SW	0.90	6
Water	distilled	20	T	0.96	2
Water	frost crystals	–10	T	0.98	2
Water	ice, covered with heavy frost	0	T	0.98	1
Water	ice, smooth	–10	T	0.96	2
Water	ice, smooth	0	T	0.97	1
Water	layer >0.1 mm thick	0–100	T	0.95–0.98	1
Water	snow		T	0.8	1
Water	snow	–10	T	0.85	2
Wood		17	SW	0.98	5
Wood		19	LLW	0.962	8
Wood	ground		T	0.5–0.7	1
Wood	pine, 4 different samples	70	LW	0.81–0.89	9
Wood	pine, 4 different samples	70	SW	0.67–0.75	9
Wood	planed	20	T	0.8–0.9	1
Wood	planed oak	20	T	0.90	2

1	2	3	4	5	6
Wood	planed oak	70	LW	0.88	9
Wood	planed oak	70	SW	0.77	9
Wood	plywood, smooth, dry	36	SW	0.82	7
Wood	plywood, untreated	20	SW	0.83	6
Wood	white, damp	20	T	0.7–0.8	1
Zinc	oxidized at 400 °C	400	T	0.11	1
Zinc	oxidized surface	1000–1200	T	0.50–0.60	1
Zinc	polished	200–300	T	0.04–0.05	1
Zinc	sheet	50	T	0.20	1

Index

D

E

F

J

K

L

M

N

O

P

T

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Description	Software	Supplier	URL
Version control	ExcoConf	Excosoft	http://www.excosoft.se/eweb/site/exc_pd.html
Editing environment	XML Client	Excosoft	http://www.excosoft.se/eweb/site/excoconf_pd.html
Preformatting	ExcoForm	Excosoft	http://www.excosoft.se/eweb/site/home.html
XML parser	Xerces	Apache	http://xml.apache.org/xerces-j
XSLT processor	Xalan	Apache	http://xml.apache.org/xalan-j
XSL-FO rendering engine	XEP	RenderX	http://www.renderx.com

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(p)20235703.xml;16
(p)20235803.xml;17
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(p)20236103.xml;11
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